California Energy Commission

STAFF DRAFT REPORT

2011-2012 INVESTMENT PLAN FOR THE ALTERNATIVE AND RENEWABLE FUEL AND VEHICLE TECHNOLOGY PROGRAM

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CALIFORNIA ENERGY COMMISSION

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PREFACE

The increased use of alternative and renewable fuels supports California's commitment to curb greenhouse gas emissions, reduce petroleum use, improve air quality, and stimulate the sustainable production and use of biofuels within California. Alternative and renewable transportation fuels include electricity, natural gas, biomethane, propane, hydrogen, gasoline substitute fuels, and diesel substitute fuels. State investment is needed to fill the gap and fund the differential cost of these emerging fuels and vehicle technologies.

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Alternative and Renewable Fuel and Vehicle Technology Program. This statute, amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), authorizes the California Energy Commission to "develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies." The Energy Commission has an annual program budget of approximately $100 million.

The statute also directs the Energy Commission to create an advisory committee to help develop and adopt an investment plan. The statute calls for the investment plan to describe how funding will complement existing public and private investments, including existing state and federal programs. The Energy Commission will use the investment plan as a guide for awarding funds. The statute calls for the investment plan to be updated annually.

ABSTRACT

The investment plan for the Alternative and Renewable Fuel and Vehicle Technology Program serves as the guidance document for the allocation of program funding and is prepared annually based on input and advice of the Assembly Bill 118 Advisory Committee. This third investment plan, the *2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program*, covers the third year of the program and reflects laws, executive orders, and policies to reduce petroleum use, greenhouse gas emissions, and criteria emissions, increase alternative fuel use, and spur the development of bioenergy sources in California. It details how the California Energy Commission, with input from stakeholders and the Advisory Committee, determined the program's goal-driven priorities coupled with project opportunities for funding. These priorities are consistent with the program's goal "to develop and deploy innovative technologies that transform California's fuel and vehicle types to help attain the state's climate change policies."

The *2011-2012 Investment Plan* provides proposed funding recommendations based on alternative and renewable fuel and vehicle technology analyses and identified opportunities. The appendices provide supporting analyses and important references for the development of this plan to help transform California's transportation sector to a low-carbon, cleaner, non-petroleum, and more efficient energy future.

Keywords: California Energy Commission, Alternative and Renewable Fuel and Vehicle Technology Program, alternative transportation fuels, investment plan, electric drive, hydrogen, biodiesel, renewable diesel, diesel substitutes, renewable gasoline substitutes, ethanol, natural gas, propane, innovative technologies, advanced fuels, workforce training, vehicle efficiency, sustainability, fueling stations, fuel production, fuel storage and blending, biofuels, biomethane

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EXECUTIVE SUMMARY

Transportation fuels is one of the top three energy use sectors in the United States, accounting for two-thirds of the 20 million barrels of crude oil consumed daily. Of that, approximately half is imported from foreign sources. In California, the transportation sector represents roughly half of all energy consumed and, like the United States, is more than 90 percent dependent on petroleum. Despite the current recession, Californians still consume more than 50 million combined gallons of gasoline and diesel each day.

This dependence on petroleum-derived fuels poses a number of significant challenges for the California. As a result of this dependence, California's transportation sector contributes about 40 percent of the state's greenhouse gas emissions, the largest amount from any sector. Forecasts of an increase in fuel prices from 35 to 50 percent by 2015 suggest a considerable drag on California's economic recovery. Finally, given our nation's dependence on foreign sources of crude oil, petroleum dependence entails national security risks as well.

California has and will continue to dramatically affect the direction of the nation's transportation sector as it leads with landmark state regulations and incentives to decrease petroleum use and greenhouse gas emissions. The *State Alternative Fuels Plan* of 2007 (Assembly Bill 1007, Pavley, Chapter 371, Statutes of 2005), jointly developed and adopted by the Energy Commission and Air Resources Board, presented strategies to increase of alternative and non-petroleum fuel use for transportation. The *State Alternative Fuels Plan* set goals to reduce petroleum dependence by 15 percent and increase alternative fuels use by 20 percent, by 2020. The alternative fuels proposed in the plan could achieve these goals and reduce greenhouse gases by 15 percent to 20 percent in the near term. Other important California regulations include the Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006), "Zero Emission Vehicle" regulations, the Low Carbon Fuel Standard, the *Bioenergy Action Plan*, the Renewables Portfolio Standard and the *San Pedro Bay Ports Clean Air Action Plan*.

The Alternative and Renewable Fuel and Vehicle Technology Program (Program), created by Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), has a crucial role in attaining the state's climate change policies. Through 2014, the Energy Commission will provide incentives up to $100 million annually through the program to leverage public and private investment to develop and deploy clean, efficient, and low-carbon alternative fuels and technologies. The program also provides a foundation for the sustainable development and use of transportation energy and an economic stimulus to create California jobs and businesses by encouraging the invention and production of the technologies and services necessary for the future transportation system. Assembly Bill 118 also provides up to $50 million per year for the Air Quality Improvement Program, administered by the Air Resources Board, which complements the Energy Commission's investment plan in providing alternative fuel vehicle incentives.

The Energy Commission is required to prepare an annual investment plan determining the program funding priorities and opportunities and describing how program funding will be used to support other public and private investments. The Energy Commission adopted the first investment plan combining funds from fiscal years 2008-2009 and 2009-2010 at the April 22, 2009, Business Meeting. The second investment plan, for fiscal year 2010-2011, was adopted at the August 11, 2010, Business Meeting. This staff draft *2011-2012 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* is the proposed funding guide for fiscal year 2011-2012.

To ensure a more comprehensive approach to the investment plan, the Energy Commission has also taken steps to restructure the analysis and organization of the plan. More emphasis is given to the "upstream" fuel issues, such as feedstocks and fuel conversion processes. This is especially reflected in the biofuels section, which includes a detailed analysis of some of the more developed and promising feedstocks. A similarly detailed analysis of biofuel conversion processes is also under development. This approach allows the Energy Commission to encourage advanced pathways for biofuels (and other fuel types) that rely on lower carbon feedstocks and more efficient conversion processes.

The Energy Commission has also reshaped the investment plan's approach to medium- and heavy-duty vehicles. Previously, these vehicles were discussed in each fuel section. For this year's investment plan, a separate medium- and heavy-duty section has been developed, which allows for a more detailed analysis of the opportunities and barriers for incorporating alternative fuels and advanced technologies into medium- and heavy-duty vehicles.

2011-2012 Investment Plan Funding Priorities

The Energy Commission will continue to provide funding to accelerate developing and deploying clean, efficient low-carbon technologies that will reduce greenhouse gas emissions and petroleum dependence, and increase alternative and renewable fuel use and in-state biofuels production. Achieving these policy objectives requires a portfolio of fuels and vehicle technologies including developing electric drive and fuel cell vehicles, producing low-carbon biofuels, increasing vehicle efficiency, and continuing deployment of natural gas and propane vehicles.

Funding priorities were evaluated based on an identified portfolio of fuels and technologies, and reflects a broad set of short-, medium- and long-term opportunities. To ensure the maximum value for the state's funding, the plan evaluates existing public and private funding that is already developing and deploying alternative and renewable fuel and vehicle technology and assesses where gaps exist and funding is required. Funding required for workforce training, sustainability studies, standards and certification, public education and outreach, and analytical support was also considered.

This investment plan recognizes the necessity to leverage existing federal, state, and local funding as well as stakeholder investments. Auto manufacturers, utilities, other stakeholders, and federal and local governments are investing in alternative fuel and advanced vehicle technologies. The Energy Commission intends to leverage these investments to accelerate the introduction and use of these fuels and technologies.

To help develop the *2010-2011 Investment Plan*, the Energy Commission has used an array of partnerships and agreements. The *2010-2011 Investment Plan* also considers:

- Program funds that have been awarded to date.
- American Recovery and Reinvestment Act of 2009 funds awarded to successful California project applicants.

- The effects of existing and anticipated regulations, including the Low-Carbon Fuel Standard, the *Bioenergy Action Plan*, the Zero Emission Vehicle regulation modifications, the Clean Fuels Outlets regulations, the Renewable Fuel Standard, the National Greenhouse Gas and Corporate Average Fuel Economy Standards for Vehicles, the Renewable Portfolio Standard, and the Clean Air Action Plan.

Program Status

The third investment plan has also benefited from the Energy Commission's recent experience in reviewing and funding projects. This process has provided useful technical and market information that impacts the investment plan and guidance for future solicitations and agreements. The program funding is heavily oversubscribed, receiving more than 300 project proposals totaling more than $1.2 billion based on the first investment plan alone. Greenhouse gas and petroleum use reductions are substantial, and the leveraged amount of public, stakeholder, and venture capital is unprecedented.

Under the first investment plan, the Energy Commission sought to help California entities successfully compete for funding under the federal American Recovery and Reinvestment Act. As a result, the Energy Commission has committed $36.5 million to California projects that have been awarded approximately $105.3 million in additional American Recovery and Reinvestment Act funds and also include $113.3 million in private funds. These funds are used to:

- Install 2,860 new electric vehicle charging sites.
- Demonstrate and deploy more than 700 medium- and heavy-duty natural gas and hybrid-electric trucks.
- Develop high energy density lithium-ion batteries.
- Provide public outreach to promote the deployment of heavy-duty natural gas vehicles.
- Establish 75 new E85 fueling stations.

The Energy Commission also issued a number of agreements (totaling $20.6 million) for:

- Certifying hydrogen dispensing equipment for retail hydrogen fueling stations and establishment of specifications for hydrogen and biodiesel fuels: $4 million
- Establishing statewide workforce training and development programs: $15 million.
- Convert state-owned hybrid-electric vehicles to plug-in hybrid-electric vehicles: $600,000
- Technical assistance in administering the Alternative and Renewable Fuel and Vehicle Technology Program: $1 million

With a significant amount of funding from fiscal years 2008-2009 and 2009-2010 remaining, the Energy Commission issued a series of additional solicitations. The Energy Commission evaluated, scored and provided an initial proposed award for each of these solicitations (Table ES-1). Several solicitations allowed the Energy Commission the ability to increase the amount available to a new specified maximum funding level, referred to as "headroom." Due to the large number of competitive proposals with passing scores, the Energy Commission provided headroom funding from the same categories identified in the 2010-11 investment plan.

Table ES-1: Non-ARRA Solicitations and Awards

Fuel Category	Funded Activity	Initial Awards (FY 08-09, 09-10) ($ Millions)	Headroom Awards (FY 10-11) ($ Millions)	Total Award ($ Millions)	Total Number of Projects
Electric Drive	Charging Infrastructure	$3.2	$2.4	$5.6	7
	Medium- and Heavy-Duty Advance Vehicle Demonstrations	$10.0	$2.0	$12.0	8
	Manufacturing Facilities and Equipment	$19.0	$5.9	$24.9	11
Natural Gas	Fueling Infrastructure	$5.7	-	$5.7	10
Biofuels	Biomethane Production	$35.1	$0.2	$35.3	10
	Diesel Substitutes Production	$2.8	$1.5	$4.3	6
	Advanced Ethanol and Gasoline Substitutes Production	$3.5	-	$3.5	2
	California Ethanol Producers Incentive Program	$6.0	-	$6.0	TBD
	E-85 Fueling Stations	$1.0	-	$1.0	1
	Upstream Biodiesel Infrastructure	$3.9	-	$3.9	3
Hydrogen	Fueling Stations	$15.7	-	$15.7	3
Total		$105.9	$12.0	$117.9	61

Source: California Energy Commission

The remaining funding from the first investment plan (approximately $13 million) will go toward upcoming agreements for hydrogen fueling infrastructure for transit, technical analysis, and gaseous fuel vehicle deployment projects (in combination with funding from the second investment plan.)

The second investment plan had $108 million for project and activity funding, based on estimated vehicle registrations, vessel registrations, identification plates and smog abatement fees. However, Californians registered fewer vehicles in 2009 than was originally estimated; as a result, only $86.4 million was available for fiscal year 2010-11. An additional $1.73 million was allocated for project monitoring, verification, and evaluation, leaving $84.67 million for projects. Of this amount, $12 million has been dedicated for headroom awards. Using the remaining funding (and a portion of the remaining funding from the first investment plan), four new solicitations will be issued by July 2011. These solicitations include:

- Regional readiness planning for plug-in electric vehicles: $1 million.
- Medium- and heavy-duty vehicle demonstration of near-commercial advanced and alternative fuel technologies: $15 million.
- Propane and natural gas vehicles: $14.5 million.
- Outreach and marketing: $1.5 million.

Additional solicitations and agreements for fiscal year 2010-11 funding will include:

- Gasoline substitutes infrastructure and fuel production: $9.6 million.
- Diesel substitutes bulk terminal storage/blending and fuel production: $7.1 million.
- Biomethane production and quality testing, and natural gas infrastructure: $6.9 million.
- Hydrogen infrastructure: $10.2 million.
- Other solicitations and agreements, as outlined in the second investment plan.

2011-2012 Investment Plan Allocations

The allocations in the investment plan are based on possible alternative and renewable fuel increases and advanced vehicle technology deployment, petroleum displacement, potential greenhouse gas reductions, the level of current public and private funding, and input from stakeholders. These allocations provide funding for demonstration and deployment opportunities in the short-, mid- and long-term to meet program goals (Table ES-2). For example, funding is being provided immediately to establish electric drive infrastructure for electric vehicles being deployed in 2011 to 2013—the near term. Funding for improved biofuel production methods will provide alternative vehicle fuels for the mid-term, and funding for hydrogen infrastructure will help to meet petroleum and greenhouse gas reduction goals for the long term as commercial fuel cell vehicles are introduced in 2015. To further support commercializing alternative fuels and vehicle technologies, the investment plan also provides funding for market and program development activities.

Table ES-2: Funding Allocation Summary for FY 2011-2012

	Project/Activity	Funding Allocation for FY (2011-2012)
Plug-In Electric Vehicles	Charging Infrastructure	$8 Million
	Subtotal	**$8 Million**
Hydrogen	Fueling Infrastructure	$3 Million
	Subtotal	**$3 Million**
Natural Gas	Fueling Infrastructure	$8 Million
	Subtotal	**$8 Million**
Propane	Light-Duty Vehicle Incentives	$1 Million
	Fueling Infrastructure	$.5 Million
	Subtotal	**$1.5 Million**
Ethanol	E85 retail	$5 Million
	Advanced Cellulosic Ethanol Production Plants	$7.5 Million
	Subtotal	**$12.5 Million**
Diesel Substitutes	Bulk terminal rack and fleet infrastructure	$4 Million
	Advanced Diesel Substitute Production Plants	$7.5 Million
	Subtotal	**$11.5 Million**
Biomethane	Pre-Landfill Biomethane Production	$8 Million
	Subtotal	**$8 Million**
Medium- and Heavy-Duty Vehicles	Deployment Incentives for Natural Gas Vehicles	$12 Million
	Deployment Incentives for Propane Vehicles	$3 Million
	Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$7 Million
	Subtotal	**$22 Million**
Manufacturing	Manufacturing Facilities and Equipment	$10 Million
	Subtotal	**$10 Million**
Workforce and Training	Workforce Development and Training Agreements	$5.5 Million
	Subtotal	**$5.5 Million**
Market and Program Development	Sustainability Studies	$2.5 Million
	Technical Assistance and Analysis	$4.5 Million
	Measurement, Verification and Evaluation	$3 Million
	Subtotal	**$10 Million**
	Grand Total	$100 Million

Source: California Energy Commission

Plug-In Electric Vehicles ($8 Million)

Sales of in-state plug-in electric vehicles are expected to rapidly increase over the next 2-3 years, as major automakers begin offering fully electric and plug-in hybrid electric vehicles. The Energy Commission and Air Resources Board are awaiting the results of a survey of major automakers regarding their anticipated plug-in electric vehicle deployments. To accelerate the deployment of these vehicles, the Energy Commission is providing $8 million to support charging infrastructure. This funding will support a broad variety of charging installations and related activities, including regional readiness planning, residential chargers, workplace commercial and public chargers, and fast chargers. These activities will be coordinated with the Air Resources Board, the California Public Utilities Commission, and the recently established California Plug-In Electric Vehicle Collaborative Council.

Hydrogen ($3 Million)

Hydrogen vehicles, including fuel cell vehicles, are expected to rapidly expand within the state over the next decade. As in previous investment plans, the Energy Commission seeks to ensure a sufficient supply of hydrogen fueling infrastructure for these vehicles. An updated survey of major automakers suggests that, despite a drop in anticipated vehicles before 2015, the number of vehicles expected after 2015 will be in the tens of thousands. Before 2015, anticipated hydrogen fueling stations should be able to provide sufficient coverage for the expected number of vehicles. This survey data will be considered as the Energy Commission develops a funding strategy for its fiscal year 2010-2011 allocation of $10.2 million. For fiscal year 2011-2012, the Energy Commission intends to focus $3 million in funding on transit demonstration opportunities.

Natural Gas ($8 Million)

Natural gas is expected to play a growing role in the state's transportation sector, in response to greenhouse gas emission reduction targets, volatile petroleum prices, and air quality standards. Significant opportunities remain for expanding the use of medium- and heavy-duty natural gas vehicles in a variety of applications. These opportunities are discussed in greater detail in the Medium- and Heavy-Duty Vehicles section of the investment plan.

A modest network of fueling infrastructure already exists for natural gas vehicles. However, many of these stations require upgrades, and increases in natural gas vehicles will only occur when range anxiety and fleet fueling operations are addressed. The Energy Commission is allocating $8 million to support the installation of new natural gas fueling infrastructure and upgrades to existing infrastructure. An expanded natural gas fueling infrastructure also creates additional opportunities to incorporate biomethane from anaerobically digested waste-based biomass feedstocks into California's transportation fueling infrastructure

Propane ($1.5 Million)

Propane, like natural gas, offers the potential for immediately reducing greenhouse gas emissions, petroleum reductions, and fuel costs for light- and medium-duty vehicles. Propane produced by renewable methods will further reduce greenhouse gas emissions from propane-fueled vehicles. Propane has been the preferred alternative fuel for rural communities and school districts that do not have access to an alternative fuel, since propane fueling infrastructure is readily available and affordable. The Energy Commission is allocating $1 million specifically for light-duty propane vehicle deployment, and $500,000 to expand propane infrastructure in Northern California. Further allocations for medium- and heavy-duty propane vehicles are discussed in the Medium- and Heavy-Duty Vehicles section of the investment plan.

Biofuels

There is a broad variety of feedstocks available for renewable biofuels. California possesses a significant volume of waste-based feedstocks, which offer a particularly excellent opportunity for expanding the production of low-carbon fuels. The Energy Commission is interested in expanding the use of low-carbon, sustainable feedstocks. Similarly, a variety of fuel conversion processes exist, and the Energy Commission expects to maximize the processes that use abundant, waste-based feedstocks. Within biofuels, the investment plan focuses on three fuel end-uses: advanced ethanol, diesel substitutes, and biomethane.

Ethanol ($12.5 Million)

Ethanol and other gasoline substitutes offer a significant opportunity for reducing both greenhouse gas emissions and petroleum use. The state's Low Carbon Fuel Standard and *Bioenergy Action Plan*, and the federal Renewable Fuel Standard, rely heavily on biofuels (including ethanol) to meet their targets. The Energy Commission is providing $7.5 million to expand in-state production for gasoline substitutes. This funding is intended for the development of new facilities that can use waste-based cellulosic feedstocks to produce a low carbon fuel.

An additional $5 million will be provided to expand E-85 dispensers and retail outlets. Given the relatively modest marginal cost for the purchase of flex-fuel vehicles, the Energy Commission is not proposing vehicle funding for this fuel category.

Diesel Substitutes ($11.5 Million)

Diesel substitutes, such as biodiesel and renewable diesel, similarly offer an immediate opportunity to significantly reduce California's greenhouse gas emissions and petroleum dependence. The same policy drivers that will accelerate ethanol and gasoline substitutes will also accelerate diesel substitutes. To accelerate the in-state production of diesel substitutes, the Energy Commission will provide $7.5 million to expand and support California's diesel substitute production plants.

The Energy Commission additionally allocates $4 million to support needed fuel terminal and distribution infrastructure for diesel substitutes. This funding will include modifications to existing rack-terminals, enabling them to dispense biomass-based diesel, and the expansion of bulk terminal and storage facility capacity.

Biomethane ($8 Million)

The production and use of in-state biomethane will further advance state policy in the transportation sector. Biomethane, when produced from waste-based resources or byproducts, possesses one of the lowest carbon intensities of any existing fuel. Additionally, biomethane can reduce the lifecycle greenhouse gas emissions in a broad variety of fuel pathways, from natural gas to hydrogen to ethanol. Anaerobic digestion of waste-based feedstocks is proving to be a robust and cost-effective technology for creating very low carbon transportation fuels that can be readily incorporated into vehicles and fueling systems that can use natural gas. The annual fuel potential from California's waste-based feedstocks is estimated to be more than 1,750 million diesel gallon-equivalents. For these reasons, the Energy Commission is allocating $8 million to develop in-state biomethane production for use in the transportation sector.

Medium- and Heavy-Duty Vehicles ($22 Million)

Medium- and heavy-duty vehicles are a significant component of California's transportation sector, accounting for a combined16 percent of the state's petroleum consumption and greenhouse gas emissions within the transportation sector. Yet, these vehicles represent less than four percent of the in-state vehicle population. Given the high amount of petroleum use per vehicle (in comparison to passenger vehicles), these vehicles offer an excellent opportunity to expand alternative fuel use, reduce petroleum consumption, and reduce greenhouse gas emissions. The Energy Commission is allocating $12 million in deployment incentives for medium- and heavy-duty natural gas vehicles, and $3 million for propane vehicles.

Advanced technologies, such as battery electric applications, hybrid hydraulics, and fuel cell technology, can also be incorporated into medium- and heavy-duty vehicles. In comparison to passenger vehicles, medium- and heavy-duty vehicles serve a broader variety of purposes, however. The early use of advanced technologies may be limited to certain niche applications. Some vehicle suppliers have already begun incorporating a variety of advanced vehicle technologies. To expand the use of these technologies, the Energy Commission will provide $7 million for the demonstration of advanced technologies in the medium- and heavy-duty sector.

Manufacturing ($10 Million)

Given the amount of venture capital invested in California's clean transportation sector, the state has the potential to develop and attract new opportunities for the manufacturing of alternative fuel vehicles and components. The Energy Commission has already made substantial investments in manufacturing. These successful projects will attract customers and production orders, and will soon require greater manufacturing capacity. State support can help ensure that these commercial-scale manufacturing plants are located in California, benefitting California with jobs, environmental benefits, and tax revenue. For fiscal year 2011-2012, the Energy Commission will allocate $10 million to fund projects that establish commercial-scale alternative fuel vehicle and component manufacturing facilities in California.

Workforce Development and Training ($5.5 Million)

Workforce development and training is a critical element in California's efforts to develop a clean transportation energy market. Skilled workers are needed to manufacture low-emissions vehicles and components, produce alternative fuels, build fueling infrastructure, service and maintain fleets and equipment, and inform on-going innovation and refinement to increase market acceptance. Training is required to respond to new technology, improve efficiencies, minimize wastage, and reduce the cost of production. As the Energy Commission funds alternative fuel and low-emission vehicle projects, it is critical that funds are allocated to assist in the development of a skilled workforce to implement and sustain those projects. The Energy Commission allocates $5.5 million for this purpose.

Market and Program Development

The Energy Commission is also allocating funding for non-fuel categories to ensure the success of this program. The Energy Commission is providing $2.5 million for sustainability studies to support commercializing renewable fuels and minimizing negative environmental impacts. Existing efforts in marketing and program outreach will continue, but do not require additional funding at this time. The Energy Commission will provide $4.5 million for technical assistance and environmental, market, and technology analysis. This work will assist the program to focus on funding priorities and identifying preferred opportunities for future funding. This category may also provide funding for full fuel cycle analysis, to assist small companies in developing and demonstrating the carbon intensity of their alternative and renewable fuels and technologies. Finally, the Energy Commission will reserve $3 million for program support for the measurement, verification and evaluation of the program’s activities.

CHAPTER 1: Introduction

The transportation sector of California represents a critical element of the state's economy and society, with more than 26 million registered vehicles. This sector accounts for nearly half of all energy consumed within the state, and produces approximately 40 percent of the state's greenhouse gas (GHG) emissions.[1] Petroleum-derived fuels account for 91 percent of all energy consumed within the transportation sector, and importation of foreign-sourced petroleum is expected to increase, even under a "low-import" case.[2] Despite the climate and economic risks associated with petroleum dependence, California and the United States have yet to take full advantage of alternative and renewable fuels and advanced vehicle technologies.

Over the past five years, however, California has begun aggressive measures to reduce GHG emissions across all sectors. In 2006, Assembly Bill 32 (AB 32) (Núñez, Chapter 488, Statutes of 2006), the Global Warming Solutions Act of 2006, was signed into law. AB 32 established a goal of reducing 2020 GHG emission reductions to 1990 levels. Governor Schwarzenegger also issued Executive Order S-3-05, setting a target of reducing GHG emissions 80 percent further by 2050. Newly-inaugurated Governor Jerry Brown has also actively supported AB 32, as well as policies to specifically reduce GHG emissions in the transportation sector.[3] In November 2010, California voters vetoed Proposition 23, which would have repealed AB 32, further demonstrating the state's commitment to reducing GHG emissions.

California recognizes the economic consequences of an overdependence on petroleum fuels. While the current recession has resulted in a modest decrease in gasoline and diesel consumption, Californians still consume approximately 50 million combined gallons of gasoline and diesel each day. As the worldwide economy recovers, and the demand for petroleum-derived fuels increases, the market price of crude oil is subject to instability. California petroleum fuel price forecasts suggest that the price of gasoline may increase from 35 percent to 50 percent (adjusted for inflation) by 2015, with similar possible increases for diesel.[4] Some sectors of the economy are likely to respond to such price increases by reducing their transportation fuel demand; in other sectors, price increases will be met with greater commitments toward alternative fuel and advanced vehicle technologies.

Petroleum dependence also entails an energy security risk. In 2008, foreign supplies of crude oil provided nearly half of the supply for California's oil refineries.[5] The United States was similarly dependent on foreign imports for approximately half of its petroleum demand, while accounting for approximately 22 percent of worldwide petroleum consumption. At a forum on naval energy, Secretary of the Navy Ray Mabus summarized these concerns, stating, "We have

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1 California Energy Commission, 2007 Integrated Energy Policy Report, CEC-100-2007-008-CMF.

2 California Energy Commission, 2009 Integrated Energy Policy Report, CEC-100-2009-003-CMF.

3 Jerry Brown 2010, "Environment," http://www.jerrybrown.org/environment, January 6, 2010.

4 Gordon Schremp, Aniss Bahreinian, and Malachi Weng-Gutierrez, 2010 Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report, California Energy Commission. CEC-600-2010-002-SF.

5 California Energy Commission, CEC-600-2010-002-SF.

ceded [a strategic resource] to other nations who are allowed to exert disproportionate influence as a result. This creates an obvious vulnerability to our energy security, and to our national security, and to our future on this planet." Taking these concerns seriously, the U.S. Navy plans to reduce its petroleum use by 50 percent in its commercial fleet by 2015, and to use alternative fuels for half of its total energy consumption for ships, aircrafts, tanks, vehicles and shore installations by 2020.[6]

The growth of new fuels and technologies also poses a significant opportunity for economic development in California. While total state employment has grown by 18 percent since 1995, growth in the green jobs sector grew by 56 percent. Employment in clean transportation increased six percent from January 2008 to January 2009.[7] The potential for growth in these sectors is also visible in the venture capital market. From 2006 to 2009, California attracted more than $6.6 billion in clean technology funding, more than half of national funding.[8] In 2009, almost $400 million of venture capital was invested specifically within clean transportation. In the first half of 2010, California attracted 40 percent of the global venture capital in the clean technology sector. As a result of these investments, California has developed a competitive edge in intellectual property in green technology, with nearly 50 percent more green technology patents than the next state.[9]

Since 2003, California has implemented a number of key policies to reduce GHG emissions, reduce the state's dependence on petroleum, increase the development and use of alternative and renewable fuels and vehicles, and stimulate in-state sustainable biofuel production and use (Table 1). Transforming California's transportation sector to achieve these objectives will require the well-planned use of state and federal funds to encourage private investment in alternative and renewable fuels and technologies.

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6 Honorable Ray Mabus, Secretary of the Navy, Remarks at the Naval Energy Forum on October 14, 2009, http://www.navy.mil/navydata/people/secnav/Mabus/Speech/Energy_Forum_14Oct09.pdf
7 Next 10, "Many Shades of Green," http://www.next10.org/next10/publications/pdf/2011_Many_Shades_of_Green_FINAL.pdf
8 Pew Charitable Trusts, "The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America," http://www.pewcenteronthestates.org/uploadedfiles/clean_economy_report_web.pdf
9 Next 10, "2010 California Green Innovation Index," http://www.next10.org/pdf/GII/Next10_GII_2010.pdf

Table 1: Summary of Key Policies

Objectives	Goals and Milestones
Petroleum Reduction[10]	Reduce petroleum fuel use to 15 percent below 2003 levels by 2020
GHG Reduction[11,12]	Reduce GHG emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050
Alternative and Renewable Fuel Use[13]	Increase alternative and renewable fuel use to 11 percent of on-road and off-road fuel demand by 2012, 13 percent by 2017, and 26 percent by 2022
In-State Biofuels Production[14]	Produce in California 20 percent of biofuels used in state by 2010, 40 percent by 2020, and 75 percent by 2050

Source: California Energy Commission

To help achieve these policies, Assembly Bill (AB) 118, (Núñez, Chapter 750, Statutes of 2007) created the Alternative and Renewable Fuel and Vehicle Technology Program (Program). The statute, amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), authorizes the Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. The Energy Commission is providing incentives to accelerate the development and deployment of clean, efficient, low-carbon alternative fuels and technologies. The program has an annual program budget of approximately $100 million for projects that:

- Develop and improve alternative and renewable low-carbon fuels.
- Reduce California's use and dependency on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Optimize alternative and renewable fuels for existing and developing engine technologies.
- Produce alternative and renewable low-carbon fuels in California.
- Decrease, on a full fuel cycle basis, the overall impact and carbon footprint of alternative and renewable fuels and increase sustainability.
- Expand fuel infrastructure, fueling stations, and equipment.
- Improve light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets.

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10 *Reducing California's Petroleum Dependence*, California Energy Commission and California Air Resources Board joint agency report, August 2003, publication #P600-03-005.

11 Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006).

12 Governor's Executive Order S-3-05.

13 *State Alternative Fuels Plan*, Final Adopted Report, CEC-600-2007-011-CMF, December 2007.

14 Governor's Executive Order S-6-06.

- Expand infrastructure connected with existing fleets, public transit, and transportation corridors.
- Establish workforce training programs, conduct public education and promotion, and create alternative and renewable fuel and vehicle technology centers.

The Energy Commission is directed to prepare an investment plan to determine funding priorities and opportunities, and describe how program funding will be used to complement other public and private investments. The Energy Commission adopted its first investment plan combining funds from fiscal year (FY) 2008-2009 and FY 2009-2010 at the April 22, 2009, Business Meeting. The statute also requires the Energy Commission to adopt a new investment plan each year. The second investment plan, governing FY 2010-2011, was adopted at the August 11, 2010, Business Meeting. This staff draft *2011-2012 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program* (2011-2012 Investment Plan) is the funding guide for FY 2011-2012.

CHAPTER 2: Determining Priorities and Opportunities

The Energy Commission's third investment plan continues to accelerate the development and deployment of clean, efficient low-carbon technologies that will achieve several key policy objectives: reducing greenhouse gas emissions and petroleum dependence, and increasing alternative and renewable fuel use and in-state biofuels production. Achieving these objectives requires a portfolio of fuels and vehicle technologies including developing electric drive and fuel cell vehicles, producing low-carbon biofuels, increasing vehicle efficiency, and continuing deployment of natural gas and propane vehicles.

Funding opportunities were evaluated based on the identified needs of a portfolio of fuels and technologies, and reflects a broad set of short-, medium- and long-term opportunities. To ensure the maximum value for the state's funding, the plan evaluates existing public and private funding that is already developing and deploying alternative and renewable fuel and vehicle technology and assesses where gaps exist and funding is required. Funding required for workforce training, sustainability studies, standards and certification, public education and outreach, and analytical support was also considered.

This investment plan recognizes the necessity to leverage existing federal, state, and local funding as well as stakeholder investments. Auto manufacturers, utilities, other stakeholders, and federal and local governments are investing in alternative fuel and advanced vehicle technologies. The Energy Commission intends to leverage these investments to accelerate the introduction and use of these fuels and technologies.

Summary of Program Activities

The Energy Commission has already begun administering the funding activities called for in the first two investment plans. The program funding is heavily oversubscribed, receiving more than 300 project proposals totaling more than $1.2 billion based on the first investment plan alone. Greenhouse gas and petroleum use reductions are substantial, and the leveraged amount of public, stakeholder, and venture capital is unprecedented.

Under the first investment plan, the Energy Commission sought to help California entities successfully compete for funding under the federal American Recovery and Reinvestment Act. As a result, the Energy Commission has committed $36.5 million to California projects that were awarded approximately $105.3 million in additional American Recovery and Reinvestment Act funds and also include $113.3 million in private funds. These funds are used to:

- Install 2,860 new electric vehicle charging sites.
- Demonstrate and deploy more than 700 medium- and heavy-duty natural gas and hybrid-electric trucks.
- Develop high energy density lithium-ion batteries.
- Provide public outreach to promote the deployment of heavy-duty natural gas vehicles.
- Establish 75 new E85 fueling stations.

The Energy Commission also issued a number of agreements (totaling $20.6 million) for:

- Certifying hydrogen dispensing equipment for retail hydrogen fueling stations and establishment of specifications for hydrogen and biodiesel fuels: $4 million
- Establishing statewide workforce training and development programs: $15 million.
- Convert state-owned hybrid-electric vehicles to plug-in hybrid-electric vehicles: $600,000
- Technical assistance in administering the Alternative and Renewable Fuel and Vehicle Technology Program: $1 million

With a significant amount of funding from fiscal years 2008-2009 and 2009-2010 remaining, the Energy Commission issued a series of additional solicitations. The Energy Commission evaluated, scored and provided an initial proposed award for each of these solicitations (Table 1). Several solicitations allowed the Energy Commission the ability to increase the amount available to a new specified maximum funding level, referred to as "headroom." Due to the large number of competitive proposals with passing scores, the Energy Commission provided headroom funding from the same categories identified in the 2010-11 investment plan.

Table 2: Non-ARRA Solicitations and Awards

Fuel Category	Funded Activity	Initial Awards (FY 08-09, 09-10) ($ Millions)	Headroom Awards (FY 10-11) ($ Millions)	Total Award ($ Millions)	Total Number of Projects
Electric Drive	Charging Infrastructure	$3.2	$2.4	$5.6	7
	Medium- and Heavy-Duty Advance Vehicle Demonstrations	$10.0	$2.0	$12.0	8
	Manufacturing Facilities and Equipment	$19.0	$5.9	$24.9	11
Natural Gas	Fueling Infrastructure	$5.7	-	$5.7	10
Biofuels	Biomethane Production	$35.1	$0.2	$35.3	10
	Diesel Substitutes Production	$2.8	$1.5	$4.3	6
	Advanced Ethanol and Gasoline Substitutes Production	$3.5	-	$3.5	2
	California Ethanol Producers Incentive Program	$6.0	-	$6.0	TBD
	E-85 Fueling Stations	$1.0	-	$1.0	1
	Upstream Biodiesel Infrastructure	$3.9	-	$3.9	3
Hydrogen	Fueling Stations	$15.7	-	$15.7	3
Total		$105.9	$12.0	$117.9	61

Source: California Energy Commission

The remaining funding from the first investment plan (approximately $13 million) will go toward upcoming agreements for hydrogen fueling infrastructure for transit, technical analysis, and gaseous fuel vehicle deployment projects (in combination with funding from the second investment plan.)

The second investment plan had $108 million for project and activity funding, based on estimated vehicle registrations, vessel registrations, identification plates and smog abatement fees. However, Californians registered fewer vehicles in 2009 than was originally estimated; as a result, only $86.4 million was available for fiscal year 2010-11. An additional $1.73 million was allocated for project monitoring, verification, and evaluation, leaving $84.67 million for projects. Of this amount, $12 million has been dedicated for headroom awards. Using the remaining funding (and a portion of the remaining funding from the first investment plan), four new solicitations will be issued by July 2011. These solicitations include:

- Regional readiness planning for plug-in electric vehicles: $1 million.
- Medium- and heavy-duty vehicle demonstration of near-commercial advanced and alternative fuel technologies: $15 million.
- Propane and natural gas vehicles: $14.5 million.
- Outreach and marketing: $1.5 million.

Additional solicitations and agreements for fiscal year 2010-11 funding will include:

- Gasoline substitutes infrastructure and fuel production: $9.6 million.
- Diesel substitutes bulk terminal storage/blending and fuel production: $7.1 million.
- Biomethane production and quality testing, and natural gas infrastructure: $6.9 million.
- Hydrogen infrastructure: $10.2 million.
- Other solicitations and agreements, as outlined in the second investment plan.

American Recovery and Reinvestment Act of 2009

President Obama signed the American Recovery and Reinvestment Act (ARRA) into law on February 17, 2009, to stimulate the economy, create jobs, and address a variety of critical areas of national concern.[15] One of the areas targeted for the economic stimulus was energy.

The initial announcement of federal funding opportunities in March 2009 for alternative and renewable fuels and advanced vehicles immediately preceded the adoption of the Energy Commission's first investment plan. To help California entities successfully compete for available federal funds, the Energy Commission issued a solicitation (PON-08-010) in April 2009 offering $175 million[16] of program funds from the first investment plan as a cost share to those who were submitting proposals to the federal government in response to a transportation-related ARRA funding opportunity announcement.

15 U.S. Department of Energy. "Recovery and Reinvestment," http://www.energy.gov/recovery.
16 This amount was later reduced to $156 million. Four million dollars for standards and certification and $15 million for workforce training and development had already been committed for specified entities in the *2008-2009 Alternative Fuels Investment Plan*.

The Energy Commission reviewed 108 proposals requesting more than $624 million of program funds and $1.815 billion of ARRA funds. Of the 108 applications, 38 percent were applying to the federal Clean Cities solicitation, 35 percent were for transportation electrification, 12 percent for biorefineries, and 10 percent for battery and component manufacturing. The remaining applications were for Transit Investments for Greenhouse Gas and Energy Production (TIGGER) and Advanced Research Projects Agency-Energy (ARPA-E).

Table 3 shows ARRA funds awarded to date for California alternative and renewable transportation projects with and without Program match funds.

Table 3: ARRA Awards with Program Match Funding in California (In Millions)

Program	Federal Funds Available	ARRA Awards with Program Match			ARRA Awards w/o Program Match
		ARRA Awards	Program Match Funds	Private/ Other Match	ARRA Awards
Transportation Electrification	$400	$75.025	$17.070	$53.182	$3[17]
Clean Cities	$300	$26.276	$18.450	$59.770	$6
ARPA-E	$400	$4.000	$1.000	$0.329	$12
Adv Battery Manufacturing	$2,000	$0	$0	$0	$0
Diesel Emission Reduction	$300	$0	$0	$0	$27
Applied RDD&D	$2,500	$0	$0	$0	$14
TIGGER	$100	$0	$0	$0	$18
Integrated Biorefinery	$483	$0	$0	$0	$45
Efficient Class 8 Trucks and Adv Tech for LD Vehicles	$115-$240	$0	$0	$0	*[18]
Algal/Adv Biofuels Consortia	$85	*[19]	$0	*[20]	$.4
Totals	$6,683-6,808	$105.301	$36.52	$113.281	$125.4

Source: California Energy Commission

17 Funding is an estimate of California's share of multistate projects.
18 A total of $187 million was awarded to major heavy-duty truck and passenger vehicles companies, and at this time it is unknown how many of the vehicles will come to California.
19 Total award of $44 million nationwide but California portion is not yet available.
20 California portion not yet available.

Air Quality Improvement Program

The California Air Resources Board (ARB) is responsible for administering the AB 118 Air Quality Improvement Program (AQIP), which provides up to $50 million per year for grants to fund clean vehicles and equipment, air quality research, and workforce training.[21]

Both AQIP and the Energy Commission's program were established by the same legislation and provide opportunities for complementary funding strategies. For example, unlike the Energy Commission, ARB cannot fund infrastructure for alternative and renewable fuels. The Energy Commission, therefore, is making significant investments in fueling and electric charging stations and fuel storage facilities.[22] Both agencies can fund vehicle technology development and commercial deployment. The Energy Commission, however, is largely funding the former while ARB is providing incentives for the latter with a focus on electric drive and zero emission vehicles. The Energy Commission also provides vehicle deployment incentives, but primarily for natural gas and propane vehicles.

As part of the FY 2008-2009 state budget, the Legislature directed FY 2008-2009 AQIP funds be used for a new ARB Truck Loan Program to assist truckers affected by the ARB regulations adopted in December 2008: the Statewide In-Use Truck and Bus Regulation and the Heavy-Duty Vehicle Greenhouse Gas Emission Reduction Measure. About $35 million is available for this program, which supplements ARB's existing grant incentive programs. Loans will be available for the purchase of new or used trucks, diesel emission control devices, and the United States Environmental Protection Agency (U.S. EPA) SmartWay technologies.[23] ARB's Truck Loan Program is designed to leverage state dollars to maximize funding opportunities and to provide credit access to truckers, so they can take early action in upgrading their fleets. The program was rolled out in the spring of 2010 with loan opportunities for truckers available in the following months.

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21 ARB, "AB 118 Air Quality Improvement Program," http://www.arb.ca.gov/msprog/aqip/aqip.htm and http://www.arb.ca.gov/msprog/aqip/meetings/aqip_workshop_presentation_120809.pdf

22 In compliance with governing statutes and regulations adopted by the ARB, projects funded by the ARB or Energy Commission must complement, and not interfere with, efforts to achieve and maintain air quality standards. Additionally, in compliance with regulations adopted by the ARB, the Energy Commission must provide supplemental evaluations of localized health impacts for any projects requiring permits. These evaluations are to ensure that projects funded by the Energy Commission do not result in disproportionate health impacts to communities with low incomes or minority populations. This information will be posted and available for public review at least 30 calendar days before being presented in a publicly noticed meeting. Health and Safety Code, Chapter 8.9, Section 44271(b), and California Code of Regulations, Chapter 8.1, Sections 2343 (b)(2) and (c)(c)(a).

23 The 2009-2010 AQIP Funding Plan page 6 explains how FY 2008-09 funds were directed to the truck loan program. ARB did not develop a funding plan for FY 2008-09 due to time constraints. The Legislature codified financial assistance for truck loans in HSC Section 44274.7. The original funding amount was $42 M, but based on revenues generated during that fiscal year, only $35 M was available.

For FY 2009-2010 total AQIP funds of about $30 million[24] are allocated to hybrid truck and bus vouchers ($20.4 million), zero-emission and plug-in hybrid light-duty vehicle rebates ($4.1 million), lawn and garden equipment replacement ($1.6 million), zero-emission agricultural utility terrain vehicle rebates ($1.1 million), and advanced technology demonstrations (about $2 million). These amounts were supplemented in the 2010-2011 funding plan, which was adopted in June 2010. The AQIP 2010-2011 plan allocates up to a total of $40 million to: hybrid truck and bus vouchers ($25 million); clean vehicle rebate project ($5 million); lawn and garden equipment replacement ($1 million); zero-emission agricultural utility terrain vehicle rebate project ($0.5 million); off-road hybrid technology pilot ($3 million for this new project); and advanced demonstration projects ($5.5 million).[25]

The Funding Plan for FY 2011-2012 is still under development.

Low Carbon Fuel Standard

Governor Schwarzenegger established the Low Carbon Fuel Standard (LCFS) by Executive Order S-01-07 in January 2007, and the ARB adopted standards and protocols on April 23, 2009. The LCFS establishes carbon intensity (grams CO_2e/MI) standards that fuel producers and importers must meet each year beginning in 2011. The 10-year LCFS schedule requires a gradual reduction in average carbon intensity for the first several years, beginning January 1, 2011, then steeper reductions, year-to-year over the remaining years, concluding with a 10 percent carbon intensity reduction by 2020. The LCFS will be reviewed periodically to update advances in low-carbon fuels, production technologies, and full cycle assessments.

Zero Emission Vehicle Regulation

The Zero Emission Vehicle regulation (ZEV) was adopted in 1990 as part of the ARB's Low Emission Vehicle Program and has been modified several times since then. It requires large automakers to produce certain percentages of "pure zero" emission and "near-zero" emission vehicles for sale in California. The goal of the ZEV regulation is to meet California's air quality goals and has resulted in the introduction of new vehicle technologies in California. As a result of the ZEV regulation, over 1 million Californians are driving partial zero and advanced technology partial zero-emission vehicles (PZEV and AT PZEV).

Automakers may comply using a variety of different types of ZEVs. While required to produce a minimum number of pure ZEVs, manufacturers can meet their remaining obligation with a variety of vehicle technology options including PZEV (partial or "near zero" ZEVs; advanced gasoline vehicles), AT PZEV (advanced technology PZEV; hybrids, NGVs), and Enhanced AT PZEV (hydrogen internal combustion engines and plug-in hybrid electric). ARB is preparing

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24 The ARB approved a funding plan for $42.3 million in April 2009 based on funds appropriated in the FY 2009-2010 state budget; however ARB expects about $30 million will be available for AQIP projects based on revised revenue projections.

25 ARB, *Proposed AB 118 Air Quality Improvement Program Funding Plan for Fiscal Year 2010-11*, http://arb.ca.gov/msprog/aqip/fundplan/AQIP_FP_JUNE%202010-FINAL.pdf

regulatory changes that move the PZEV and AT PZEV categories from the ZEV program to the Low Emission Vehicle (LEV) and Pavley programs by 2020.[26]

Zero Emission Bus Regulation

The ARB's Zero Emission Bus (ZEB) regulation was adopted in 2000 as part of the Transit Fleet Rule. It affects only large transit agencies with more than 200 buses and includes a 15 percent fleet ZEB purchase requirement. Ten agencies are affected, with six in Northern California and four in Southern California. Two compliance paths are offered: the diesel path (2011-2026 timeframe for purchase requirement) and the alternative fuel path (2012-2026 time frame for purchase requirement), which includes fuel cell buses and battery-operated buses.

Bioenergy Action Plan

On April 25, 2006, Governor Schwarzenegger issued Executive Order S-06-06, which established targets for the use and production of biofuels and biopower and directed state agencies to work together to advance biomass programs in California. The Bioenergy Interagency Working Group is working to meet the goals of the *Bioenergy Action Plan* (BAP) [27] which include maximizing the contribution of bioenergy toward achieving the state's petroleum reduction, climate change, renewable energy and environmental goals. The Executive Order established targets to increase the production and use of bioenergy, including ethanol and biodiesel fuels from renewable resources. For biofuels, the state's goal is to produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050. Regarding the use of biomass for electricity, the goal is for 20 percent of the state's Renewables Portfolio Standard targets for renewable generation for 2010 and 2020 to be met with biomass resources.[28]

Renewable Fuel Standard

The Energy Policy Act of 2005 established the federal Renewable Fuel Standard (RFS) Program. The United States Congress gave the U.S. EPA the responsibility to coordinate with the United States Department of Energy (U.S. DOE), the United States Department of Agriculture (USDA), and stakeholders to design and implement the RFS program. With the passage of the Energy Independence and Security Act (EISA) of 2007, Congress made several important revisions to the RFS.

As of January 1, 2010, the new RFS-2 increased the total renewable fuel required to be used as transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022. Of the four standards, the cellulosic biofuel requirement grows most significantly at 100 million gallons in

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20 Assembly Bill 1493 (Pavley, Chapter 200, Statutes of 2002), known as the Pavley Bill, requires ARB to adopt regulations for the reduction of GHG emissions from motor vehicles. More information is available on the ARB's website: http://www.arb.ca.gov/cc/ccms/ccms.htm.

27 Publication Number CEC-600-2006-010, July 2006.

28 The *2010 Bioenergy Action Plan* is under development. Workshops were scheduled for June and September with possible adoption of the *Bioenergy Action Plan* in November 2010.

2010 to 16 billion gallons in 2022, 1 billion gallons more than corn-based ethanol (15 billion gallons that year).[29]

Parties (refiners, importers, and blenders) have minimum yearly calculated volumetric blending obligations that gradually rise between 2009 and 2022. Not surprisingly, the RFS-2 will increase demand for ethanol and biodiesel. Companies can generate Renewable Identification Number (RIN) credits for excess renewable fuel use, which may be purchased or sold for compliance purposes.

National Greenhouse Gas and Corporate Average Fuel Economy Standards

On September 15, 2009, the U.S. EPA and the United States Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) proposed a historic national program that would dramatically reduce GHG emissions and improve fuel economy for passenger cars, light-duty trucks, and medium-duty passenger vehicles for model years 2012 through 2016.

The combined U.S. EPA and NHTSA standards require these vehicles to meet an estimated combined average emissions level of 250 grams of carbon dioxide (CO_2) per mile, equivalent to 35.5 miles per gallon (MPG) if the automobile industry were to meet this CO_2 level solely through fuel economy improvements.[30] Together, these proposed standards would reduce CO_2 emissions by an estimated 950 million metric tons and 1.8 billion barrels of oil over the lifetime of the vehicles sold under the national program (model years 2012-2016).

Under this proposed national program, automakers will be able to build a single light-duty national fleet that satisfies all requirements under both the national program and the standards of California and other states, while ensuring that consumers still have a full range of vehicle choices.[31] Automakers will also be able to earn, trade, and bank credits if their fleet average is better than the standard for that year. Certain vehicle types, including battery electric vehicles, plug-in hybrid electric vehicles, fuel cell vehicles, and (for a limited number of model years) flex-fuel vehicles, will earn additional credits compared to conventional vehicles.

Renewable Portfolio Standard

California's Renewables Portfolio Standard (RPS) was established by Senate Bill 1078 (Sher, Chapter 516, Statutes of 2002), and amended by Senate Bill 107 (Simitian and Perata, Chapter 464, Statutes of 2006) and Senate Bill 1036 (Perata, Chapter 685, Statutes of 2007). It requires electric corporations to increase procurement from eligible renewable energy resources by at least 1 percent of their retail sales annually, until they reach 20 percent by 2010. In Executive

29 The RFS includes four categories including Biomass-Based Diesel, Cellulosic Biofuel, Total Advanced Biofuel and Total Renewable Fuel. RFS-eligible corn-based ethanol is the difference between Total Renewable Fuel and the sum of the other three categories. Source: EPA Table "RFS2: 4 Separate STDS."
30 A/C and tailpipe emissions represent an additional potential CO2 savings of 13.5 percent of fuel economy standards.
31 United States Environmental Protection Agency, "Regulations and Standards," http://www.epa.gov/oms/climate/regulations.htm.

Order S-14-08, Governor Schwarzenegger established a more aggressive goal of 33 percent by 2020. This higher goal is a key strategy for meeting the state's GHG emission reduction targets[32] and has implications for potential GHG reductions for electric vehicles.

On September 15, 2009, Executive Order S-21-09 ordered that the ARB, under its Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) authority, adopt a regulation consistent with the 33 percent renewable energy target by July 31, 2010. The ARB is also directed to work with the California Public Utilities Commission (CPUC), the Energy Commission, and the California Independent System Operator to encourage the creation and use of renewable energy sources built upon the RPS program and may increase the target and accelerate and expand the time frame based on a thorough assessment of relevant factors.[33]

Clean Air Action Plan

On November 20, 2006, the Port of Los Angeles and Port of Long Beach both adopted the San Pedro Bay Ports Clean Air Action Plan (CAAP).[34] The goal of the CAAP is to reduce port-related air pollution, including particulate matter, nitrogen oxide, and sulfur oxide, by at least 45 percent by 2012. As part of the CAAP, the ports are implementing a Clean Trucks Program[35] (CTP), which aims to reduce heavy-duty drayage truck-related air pollution by 80 percent by 2012. Part of the CTP requires the scheduled phase-out of trucks that do not meet the 2007 federal emission standards. Beginning January 1, 2010, pre-1994 diesel trucks and certain non-retrofitted 1994-2003 trucks will be banned from use in the ports. About 7,000 drayage trucks in the ports already meet federal emission standards, 1,500 trucks that have received funding were delivered in April 2010, and an additional 500-600 of the 2004-2006 trucks will require replacement by 2012.[36]

Both ports also offer incentives for fleet owners to replace older trucks with newer, cleaner trucks. In particular, the Alternative Fuel Vehicle Funding Program, funded by the ports, the South Coast Air Quality Management District (SCAQMD), and ARB (with Proposition 1B funds), offers $50 million to provide incentives for the purchase of natural gas trucks for use within either of the ports.

32 Energy Commission, "Renewables Portfolio Standard (RPS) Proceeding – Docket # 03-RPS—1078," http://www.energy.ca.gov/portfolio/, and California Public Utilities Commission, "California Renewables Portfolio Standard," http://www.cpuc.ca.gov/PUC/energy/Renewables/index.htm.
33 Office of the Governor, "Executive Order S-21-09," http://www.gov.ca.gov/executive-order/13269.
34 Port of Los Angeles, "San Pedro Bay Ports Clean Air Action Plan," http://www.portoflosangeles.org/environment/caap.asp.
35 Port of Los Angeles, "Clean Truck Program," http://www.portoflosangeles.org/ctp/idx_ctp.asp.
36 Energy Commission staff conversation with Thomas Jelenic, March 24, 2010.

Chapter 2: Alternative Fuels and Vehicle Technologies

Plug-In Electric Vehicles

The initial wave of new generation plug-in electric vehicles (PEVs) is entering the transportation sector of California, the Nation and the world. Automakers announce their plans almost daily for new electric vehicle models. The President recently unveiled new initiatives to make the United States the world's leader in manufacturing and deploying advanced technology vehicles with specific plans to support PEVs. California regions such as the Bay Area and Southern California have made giant strides in PEV readiness, with grass roots efforts to prepare the way for this new means of transportation. The California PEV Collaborative has organized a broad array of stakeholders to leverage existing efforts and help California "Take Charge" in the global transition to PEVs.[37] The Energy Commission has made $17.14 million in awards to upgrade existing sites and install new charging infrastructure in California over the next two years. The Air Resources Board is funding the Clean Vehicle Rebate Program to provide incentives for consumers as they purchase qualified electric vehicles. The federal tax credit has significantly reduced the upfront cost of electric vehicles. Utilities are designing rates to encourage consumers to charge off-peak and working with automakers and infrastructure providers to safeguard the grid. The California Public Utilities Commission has been conducting a rulemaking to consider alternative-fueled vehicle tariffs, infrastructure and policies to support GHG reduction goals. Much is being done to address the barriers to commercialization, but much more is needed.

The Energy Commission is proposing investments in PEV charging infrastructure to help achieve its goal of petroleum and greenhouse gas reduction. Battery electric vehicles (BEVs) are 65 percent to 70 percent lower in full fuel-cycle emissions than that of conventional vehicles based on California's present electricity grid.[38] As California shifts to an increasingly renewable electricity generation system, PEVs will account for fewer GHG emissions. Full fuel cycle emissions of plug-in hybrid electric vehicles (PHEVs) are estimated to be 50 percent lower than conventional gasoline vehicles. This depends on the proportion of miles driven in electric mode, which is a function of battery capacity and driver behavior.

The investments proposed in this Investment Plan will remove some of the key barriers to successful PEV commercialization. A priority is charging infrastructure for residences, including multi-family dwellings as well as workplace and fleet charging. Regional PEV readiness will smooth the way for local infrastructure plans and the streamlining of permitting and inspection processes. Consumers need to overcome "range anxiety" and want to know public chargers will be available in areas where awards have not yet been made and on highway corridors. These investments should encourage off-peak charging or mitigation of on-peak charging via renewables such as photovoltaic charging. The vehicles are being deployed

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37 California Plug-in Electric Vehicle Collaborative, "Members," http://www.evcollaborative.org/members

38 ARB, "Low Carbon Fuel Standard Program," http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

and infrastructure must be established to support a successful PEV rollout, especially during this initial phase.

Electricity Generation

Although PEV charging will increase statewide demand for electricity, it is unlikely to require new power plant or transmission line capacity. By 2020, PEVs are expected to increase annual electricity demand on a statewide basis by roughly 4,400 gigawatt-hours (approximately 1.4 percent) and peak demand by roughly 190 megawatts (approximately 0.3 percent). The electricity demand forecast accounts for these minor increases.[39] Overall, the introduction of PEVs will not seriously impact statewide electricity generation or transmission.

California's generation mix in 2020 is expected to have 40 percent lower carbon emissions than in 2008. California's 2008 electricity grid already has 35 percent lower carbon emissions than the U.S. grid. The Renewables Portfolio Standard requires retail sellers to increase renewable energy as a percentage of their retail sales by 20 percent by 2010 and 33 percent by 2020.[40] The reductions in GHG emissions over time resulting from electricity generation will directly benefit the carbon emission reduction calculations of PEVs.

Electricity Distribution

As more PEVs enter the market, grid impacts may become more apparent at the local distribution level. The "cul-de-sac" effect of additional electricity load added to neighborhood distribution lines due to the purchase of PEVs could cause reliability problems and could shorten the life of equipment. One or two PEVs could be the energy equivalent of adding an additional home to the neighborhood. Utilities can plan for and prepare local distribution infrastructure for PEVs if notified soon enough. Therefore, utilities are working closely with automakers and other stakeholders to ensure timely notification of utilities regarding additions to load due to PEV deployment.

The development of the smart grid will facilitate high numbers of PEVs and allow them to operate effectively without causing major disruptions on the utility grid. Communication between chargers, vehicles and the utilities will allow customers to take advantage of lower off-peak charging rates. PEVs could also be used as grid assets and provide ancillary services for grid operators when parked in facilities where commercial energy service providers can aggregate their loads into one single energy response system.[41] The smart grid can also facilitate PEV electricity use billing, wireless monitoring, and data gathering.

Electric Drive Charging Infrastructure

As automakers roll out PEVs over the next year, the widespread availability of charging infrastructure will be critical to the success of commercialization. Residential chargers for single and multi-family dwellings will be the primary method of charging for most consumers, but workplace, commercial and public charging and corridor fast charging will also be essential to

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39 Kavalec, Chris and Tom Gorin, 2009 "California Energy Demand 2010-2020, Adopted Forecast," California Energy Commission. CEC-200-2009-012-CMF

40 Executive Order S-14-08 and S-21-09.

41 California Energy Commission, *2009 Integrated Energy Report*, Final Commission Report, December 2009, CEC-100-003-CMF

reduce “range anxiety” as consumers adjust to this new technology. Charging sites will also be installed for fleet vehicles and medium-duty and heavy-duty electric trucks and transit buses. In order to facilitate the deployment of these chargers, California’s regions will need to develop strategic charging infrastructure deployment plans and streamline the permitting process and installation of charging infrastructure. In the past several months, progress has been made toward addressing these challenges.

Over the 2011-2012 period there will be significant investment in California’s charging infrastructure. The federal government’s ARRA funds matched with Energy Commission Program funds and other private and public funds are providing PEV charging infrastructure to support the deployment of PEVs in California. Table 4 below summarizes the planned deployment of PEV charging infrastructure in four strategic PEV regions: the nine county Bay Area, San Diego and Los Angeles Regions, and the Sacramento Region.

Table 4: Planned PEV Charging Infrastructure Deployment by California Region[42]

Region	Public/Commercial	Fast	Battery Switch
Bay Area	3,841	55	5
Los Angeles	657		
San Diego	2,300	60	
Sacramento	331		
Other	3		
Total	7,132	115	5

Source: California Energy Commission

In the San Diego and Los Angeles regions, Program funds of $8 million and ARRA cost share funds of $39.35 million will be used to deploy 2,300 Level 2 chargers and 60 fast charging stations in residential and commercial sites. This will support the introduction of 1,000 Nissan Leafs in the near term, and eventually up to 5,000 Leafs.

The Program will also fund Coulomb Technologies with $5 million in federal ARRA match share to install and upgrade up to 1,290 Level 2 public chargers in the Bay Area, Sacramento and the Los Angeles areas. The Association of Bay Area Governments is awarded about $1.5 million with additional local match share to install about 413 charge points of which 171 are Level 1, 223 are Level 2 chargers and 19 are fast chargers. This award will supplement the Bay Area Air Quality Management District (BAAQMD two-phased infrastructure deployment. The first phase is for $1.3 million for 402 EVSE’s 6 fast chargers and one battery switch station to be installed by the end of 2011. The second phase is a $3.9 million award for 2,750 Level 2 residential chargers (with a $700 incentive per charger) provided by Coulomb (500), Aerovironment (500), Clipper Creek (250) and Ecotality (1,500 as part of the “EV Project”). Also included are 30 corridor fast chargers by mid-2012. [43] Remaining funds will be used for additional residential or commercial chargers based on the results of a regional analysis of PEV infrastructure.

42 Based on estimates of known planned deployment through 2013 (may not include all planned chargers).

43 Karen Schkolnick, Bay Area Air Quality Management District, February 2, 2011

The Bay Area's Metropolitan Transportation Commission will provide additional PEV support with four battery switch stations for taxi cabs, $2.8 million for 90 PEVs and 90 charging stations and $1.7 million to "City Car Share" for the purchase of 29 PEVs, including 12 Nissan Leafs.

In the Sacramento region, 206 chargers will be funded by ARRA funds, SMUD and the EV Sacramento Coalition to demonstrate 34 Volts. Program funds of $.553 million will be used for data collection and analysis. A similar SMUD project will deploy 35 chargers to support the deployment of 9 Chrysler PHEV vans and 11 Dodge PHEV pickups.

The Energy Commission is also updating 500 chargers to the (SAE) J1772 standard in California with an award of $2.3 million to Clipper Creek, including funds to update the chargers with new utility communication protocols.

In July 2010, the California Plug-In Vehicle Collaborative, an ad hoc group of high-level stakeholders, convened to begin work on a plan to develop a roadmap for the commercialization of PEVs in California. In December 2010, the Collaborative, with the U.C. Davis Institute of Transportation Studies PHEV and BEV Research Center, produced a plan, "*Taking Charge—Establishing California Leadership in the Plug-In Electric Vehicle Marketplace.*" [44] The Plan sets forth goals, recommendations and suggested actions to provide guidance for the market launch, growth and takeoff phases of PEV market development. Some of these suggested actions will be addressed in this section. In 2011-2012, the PEV Collaborative will work to implement the recommendations and actions and convene multi-stakeholder workgroups and meetings.

In October, 2010, the Energy Commission, in coordination with the Collaborative, held a joint PEV Charging Infrastructure Workshop.[45] The public workshop provided a forum to discuss key PEV infrastructure issues important to the rollout of PEVs in California, including input to the Collaborative's Plan and the development of the Energy Commission's infrastructure guidance document. The key findings from this workshop will be included in the next sections on PEV charging.

Regional PEV Readiness

Significant regional planning efforts for PEV infrastructure continue to develop in the key PEV rollout areas such as San Diego, Los Angeles, the Bay Area and the Sacramento region. The Energy Commission is encouraging regional coordination with the release of a $1 million non-competitive solicitation available to all California regions. This solicitation will allow regional government entities such as metropolitan planning organizations or councils of government to apply for funds to develop regional PEV strategic plans and best practices and guidelines for EVSE deployment, including PEV-friendly building and public works guidelines, PEV charger installation and permitting processes and consumer awareness programs. Some regions may lead the way by sharing their guidelines and best practices with other regions that are just

44 California Plug-in Electric Vehicle Collaborative, "Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace," http://www.evcollaborative.org/evcpev123/wp-content/uploads/2010/07/Taking_Charge_final2.pdf

45 Meeting transcript and presentations are available at: http://www.energy.ca.gov/2010-ALT-1/documents/index.html

beginning to establish PEV strategic plans. Currently, a group called "Ready, Set, Charge California!" is drafting "Guidelines for Developing an EV Ready Community." [46] This document will be have two versions, one for policy makers and local government and another suited for a technical audience including engineers, architects, and electricians. These guidelines could be adopted for statewide use and then revised by each California region to meet local needs.

President Obama recently announced plans to reward communities that invest in PEV infrastructure through competitive grants. This new initiative would provide grants to up to 30 communities that are prioritizing advanced technology vehicle deployment. Statewide regional efforts toward getting communities "EV Ready" will potentially leverage up to $10 million in additional federal funds for each region on the "basis of their ability to demonstrate concrete reforms and use the funds to help catalyze electric vehicle deployment." [47]

The permitting, installation, and inspection of residential charging infrastructure needs to be seamless. The process will vary for each community and for each installation, but on the whole, it is complex, costly, and protracted. The average residential installation time between ordering and installing charging equipment can be more than four weeks. Although the actual charging panels may take only a few hours to install, the entire process depends on a series of site visits including the utility company, licensed electrician, city permitting office, and city building inspector. Regions are currently brainstorming to find ways to streamline the process and reduce the time for installation. It is also important to provide education to local government jurisdictions that often lack knowledge about the permitting process for PEV charging infrastructure and provide assistance to permit and inspection offices facing workforce reductions. The California PEV Collaborative has identified the following actions that can help to streamline the process: [48]

- Coordinate among auto dealers, electrical contractors, utilities, and local authorities to minimize red tape
- Designate local contacts to respond to consumer questions about PEV charging
- Develop automated inspection reporting executed at the time of inspection
- Develop clear installation procedures and disseminate widely using the clearinghouse and other mechanisms
- Develop online applications for local inspections and permitting

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46 Ready, Set, Charge California!, "Guidelines for Developing an EV Ready Community," January 26, 2011.
47 White House, "Our Plan to Put One Million Advanced Technology Vehicles on America's Roads," http://www.whitehouse.gov/blog/2011/01/26/our-plan-put-one-million-advanced-technology-vehicles-america-s-roads
48 California Plug-in Electric Vehicle Collaborative, "Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace," http://www.evcollaborative.org/evcpev123/wp-content/uploads/2010/07/Taking_Charge_final2.pdf

- Establish 24-hour phone or Internet-based scheduling for inspections
- Establish set fees and consolidate inspections
- Prioritize applications for residential charging equipment in the permit review process
- Provide customers information about installation incentives, costs, options, and trade-offs through an information clearinghouse or other mechanisms, such as PEV consultations
- Seek compliance from nationally recognized testing laboratories (such as Underwriters Laboratory, Inc.) for dual-meter adapters

The Energy Commission will provide $ 1 million for projects that will support streamlining of permitting, installation and inspection of residential charging infrastructure.

PEV Electrical Vehicles Support Equipment (EVSE)

In order to recharge a PEV, EVSE is needed to safely deliver energy from the electric circuit to the vehicle. A charger converts electricity from alternating current (AC) from the electricity source to direct current (DC) required for the battery. It also converts the incoming 120 or 240 volt current to 300 or higher volts. PEVs carry an on-board charger capable of accepting AC current from a Level 1 or 2 charging station. The SAE J1772 connection standard allows for delivery of up to ~19 kW to an on-board vehicle charger. All known PEV on board chargers are expected to provide at least 3.3 kW charging when connected to a Level 2 charging station. For higher capacity charging, a charging station that delivers DC current to the vehicle is incorporated off-board in the wall or mounted pedestal.[49]

There are four options that provide various levels of service for recharging a PEV as shown in Table 5.[50] Level 1 is provided by a typical household outlet and is best for PEVs with relatively small battery packs, low daily mileage, or limited access to Level 2 charging. Level 1 charging allows PHEVs and small BEVs to fully charge overnight.

Level 2 can reduce the time it takes to recharge a PEV in half but may require the homeowner to upgrade their electrical panel to provide a dedicated circuit for PEV charging. A clothes dryer outlet is not recommended for recharging a PEV as it does not have sufficient amperage. The connectors for Level 1 and 2 charging are the same and most PEVs are compatible with both voltage levels.

Level 3 or (DC) charging (also commonly referred to as "fast charging") requires a permanent installed charging station which converts three-phase AC electricity to DC. The North American standard for uniform DC charging is currently being developed. Some demonstration programs and production PEVs incorporate fast charging at a rate sufficient to charge a 24 kWh battery to about 80 percent capacity in about 30 minutes.

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49 U.S . Environmental Protection Agency National Highway Traffic Safety Administration, and California Air Resources Board, "Interim Joint Technical Assessment Report: Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2017-20125," September 2010.
50 Ibid

Battery switch stations (BSS) would accommodate the replacement of a discharged battery pack with a fully charged battery pack in within several minutes. BSS deployment would enable third-party ownership, ease of battery replacement for servicing and use in secondary applications. These stations are being demonstrated by "Better Place" in various locations around the world, including a taxi cab demonstration project in the Bay Area.

Wireless charging, which enables PEVs to be seamlessly charged without operator interaction, is on the horizon. A SAE taskforce launched in October 2010 hopes to deliver the first J2954 SAE guideline by the end of 2011, to be published in 2012.[51] Charging locations under consideration include residential, on-road (static and dynamic), with Level 1, 2, and 3 capability—the latter for buses.[52]

Most chargers will come with "smart" components to coordinate the vehicle's charging and user preferences with the needs of the power grid. Smart chargers will ensure utilities can measure and control charging and optimize electricity transmission and distribution.

Table 5: Charging Level Definitions

Level 1	120V alternating current (AC), single phase, 12-16 amps continuous.
Level 2	240v AC, single phase, up to 80 amps continuous, typically 12-32 amps.
DC Charging	Converts three-phase AC electricity to DC off-board the PEV, delivering up to 250 kW directly to the PEV battery.
Battery Switching	An automated process exchanges a depleted battery with a fully charged battery in less time than it takes to refuel at a gas station.

Source: California Energy Commission

EVSE Costs

Significant potential exists for EVSE costs to decline over the next several years as competition among EVSE companies increase and as economies of scale result from increased EVSE production. Within the past year, there have been significant cost reductions for residential charging stations by some providers and the downward trend is likely to continue. Recently, for example, Ford announced a partnership with Best Buy to offer a level 2 charging station for owners of the new Ford Focus BEV for approximately $1,500 for a standard installation—about one third less than competitor's systems.[53]

SB 1340 allows PEV charging stations to be included in Property Assessed Clean Energy (PACE) programs. Consumers can avoid the upfront cost of PEV charging installation and eliminate concerns that they will sell their property before recovering the system investment.

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51 Green Car Congress, "SAE taskforce developing standards for wireless charging for plug-in vehicles; targeting first guideline by end of 2011," http://www.greencarcongress.com/2011/01/j2954-20110107.html
52 Ibid.
53 PR Newswire, "Ford Working With Best Buy to Offer Focus Electric Charging Station Sales, Installation and Support", 1/10/11.

Charging station costs are variable depending on the level of service, location, type of station and installation requirements, including electrical upgrading requirements. Estimated costs of charging stations are shown in Table 6.

Table 6: Estimated Costs for Charging Stations

Level	Location	Equipment	Installation
1	Single Residence	$30- $200 (charge cord only, included at no cost to consumer with EV/PHEV) when an accessible household plug (e.g., in a garage or adjacent to a driveway) with a ground fault interrupter is already available	$400-$1000+ may be necessary depending on difficulty of installing a new circuit at the desired location, but in most cases, owners with sufficient panel capacity would opt for a more capable 220 VAC Level 2 installation instead of a Level 1 dedicated circuit because the additional installation cost is only marginally higher.
2	Residential, Apartment Complex, or Fleet Depot	3.3 kW EVSE (each): $300-$4,000 6.6 kW EVSE (each): $400- $4,000	3.3- 6.6 kW installation cost: $400-$2,300 without wiring/service panel upgrade, or $2,000-$5,000 with panel upgrade.
2	Public	$400-$3,800+ for each EVSE	$3,000- $7,000+ installation cost, varying significantly with distances from service entrance and number of EVSEs installed.
3	Public	$8,000-$50,000 for fast chargers	

Source: U.S. Environmental Protection Agency National Highway Traffic Safety Administration, and California Air Resources Board, September 2010

Residential Charging

One of the attractions of PEVs compared to internal combustion engine vehicles is the convenience of home charging instead of fueling at a gas station. Predictions are that in the early market, 95 percent of charging will either be at home or at fleet facilities.[54] Forty percent of homes are likely to rely on Level 1 charging and 60 percent will likely opt for Level 2 charging.[55] Surveys show that consumers have a strong preference for home charging and rarely use public chargers.[56] [57] Most PHEVs can charge from a typical 120 V household outlet (Level 1); however Level 1 charging for a typical BEV such as a Nissan Leaf, for example, would provide only 4 to 5 miles of range per hour of charging. Most consumers would prefer Level 2 charging which

54 ICF International Draft Report, "Technical Analysis for Alternative and Renewable Fuel and Vehicle Technology Program, September 2010.

55 Summary of SCE Comments on the CPUC Order Instituting Rulemaking (OIR) to Consider Alternative-Fueled Vehicle Tariffs, Infrastructure and Policies to Support California's Greenhouse Gas Emissions Reduction Goals, Morton Blatt December 2009

56 Characterizing Consumers' Interest in and Infrastructure Expectations for Electric Vehicles: Research Design and Survey Results. EPRI, Palo Alto, CA and Southern California Edison, Rosemead, CA: 2010. 1021285

57 BMW, Presentation by Andreas Klugescheid given at the October 19, 2010 Joint Energy Commission and PEV Collaborative PEV Infrastructure Workshop.

would provide 12 to 15 miles per hour of charging.[58] Charging at Level 2 will require an electrical panel upgrade, adequate wiring to the charging location, EVSE equipment and city and county permits for any electrical or land use changes. A large percentage of homes will require the installation of a 220/240 V plug in their garages or parking shelters. This installation is an additional cost that will extend the payback period for PEVs.

Several automakers are teaming up with charging infrastructure companies as their PEVs roll out. GM is partnering with SBX to provide Volt customers with Level 2 chargers and one-stop shopping, setting up permits, rebates and sending out the electrical contractor. The cost of the charger is $490 with installation costs about $1,500 and takes four to six hours to install. Nissan is partnering with ECOtality in the San Diego and Los Angeles regions to provide home installation of level 2 chargers as part of its initial roll out. Mitsubishi will partner with Eaton and Best Buy to sell and install Level 2 home charging stations. The Best Buy "geek squad" will handle the consultation and installation for the charging units, including coordination with third-party licenses electrical contractors if needed.

The broad consensus is that residential charging is the highest priority for deployment because consumers like the convenience and it encourages charging during periods of off-peak electrical demand.[59] The Energy Commission intends to support the continued deployment of PEVs and home charging by providing consumers with $1 million in grants to fund $500 incentives per BEV customer to help cover the cost of residential EVSE.

Many utilities are developing time-of-use rates for PEV consumers to encourage off-peak electricity usage. San Diego Gas & Electric Company is conducting a time-of-use rate demonstration project for the Volt in coordination with the Nissan-ECOtality project that will analyze the electricity price elasticity of demand for PEV charging. The three time-of-use rates offered will have a ratio of on-peak to off-peak rates of two, four and six to one compared to the current two to one ratio.[60]

Electricity rates can encourage vehicle owners to charge their vehicles at those times that best protect grid safety, reliability and efficiency. Most California utilities already have some rate structures in place that encourage off-peak charging, and the current CPUC Alternative-Fueled Vehicle Rulemaking is considering additional and revised rate and tariff policies to further encourage off-peak charging and to manage the transmission and distribution impacts of PEV loads. Utilities, regulators, local governments and consumer representatives are collaborating to develop and demonstrate pricing options, including time-of-use rate structures that convey the supply and demand balance of electricity. Sharing and clearly communicating pricing information with consumers can reward them with low-cost electricity for off-peak charging.[61]

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58 Electrification Roadmap, Revolutionizing Transportation and Achieving Energy Security, Electrification Coalition November 2009

59 October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Residential Panel discussion.

60 Joel Pointon, Presentation at the U.C. Davis Institute for Transportation Studies STEPS Conference, January 19, 2011.

61 Eileen Tutt, California Electric Transportation Coalition, response to Staff inquiry 1/17/11.

Many California utilities already have rate structures in place that are intended to encourage off-peak charging. These may be modified as data is collected and based on the CPUC rulemaking. They will vary depending on utility-specific factors including rate structure, type of charging in a service territory, measurement options and consumer acceptance. Presently, many California utility customers have the option of selecting a "whole-house" time-of-use rate that bundles the vehicle charging with the home, and offers a very low super off-peak rate (balanced by higher on-peak rates). Another common rate available to PEV customers measures vehicle usage separately from the home and, similarly, provides a favorable off-peak rate. Some specific examples for utilities include:

- LADWP has two options for PEV owners. The first would require a separate meter for the PEV and the customer receives a discount on off-peak electricity of $0.025/kWh. The second allows the customer to sign up for a time-of-use rate for the entire residence and that residence would receive a discount on off-peak electricity of $0.025. In both cases the discount saves PEV customers about 10 percent if they charge their PEV off-peak.
- At PG&E, PEV customers can sign up for time-of-use rates that discount off-peak electricity $0.035-$0.05/kWh relative to partial peak and as much as $0.23/kWh relative to on-peak. This rate structure saves PEV customers 35 percent to as much as 80 percent if they charge their PEV off-peak.

Work still needs to be done to best determine how rates influence customer behavior and should be structured; different rate strategies may be preferred depending upon type of charging and location, the technologies available for measurement and load control, and consumer acceptance. Overall, the utilities' objective is that rates encourage customers to charge their vehicles during off-peak hours of the day. [62]

Smart charging, which facilitates the timing of the vehicle's charging, is a critical component of residential charging since it could actually occur on-peak during the early evening hours. A smart charger would ensure that charging occurs during the later off-peak hours.[63] The type of metering required for various functionalities including smart charging will be decided in the second phase of the CPUC's Alternative Fuel Rulemaking. The CPUC Staff paper regarding the utility role in PEV charging recommends that in the next 12-36 month period, utilities should encourage single family residential customers to use a single meter arrangement for PEVs to avoid the possible stranded costs of a separate meter. This will more easily facilitate the early adoption of PEVs in the market. Secondly, utilities should establish a protocol to establish a system that informs the utility of when a customer purchases a PEV without violating personal privacy issues. In the longer term, utilities should propose tariffs that support single, sub and separate metering options with minimum metering requirements. [64]

In dense urban areas and population centers, not every household will have access to a dedicated parking space. This is particularly challenging in California because consumers in

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62 Ibid

63 Ibid

64 CPUC, "The Utility Role in Supporting Plug-In Electric Vehicle Charging" Staff Issues Paper, August 30, 2010.

areas such as San Francisco and Los Angeles are likely to adopt PEVs faster than consumers in other areas. While in California up to half of residents do not own a home, in the San Francisco area, about 80 percent of the population does not have access to a garage.[65] About half of new car buyers have a place to charge overnight within 25 feet of an outlet. In situations where dedicated parking is not available, consumers need a way to charge. The multi-dwelling unit (MDU) situation is complex and therefore solutions must be diverse.

One consideration with MDUs is that the apartment or condominium owner must be involved in any siting decisions. While the PEV consumer will prefer a charging site close to the consumer's dwelling, the MDU owner may have other things to consider such as lighting and vandalism concerns, flooding or drainage conditions and payment methods.[66] Homeowner associations must be consulted in some cases as well. SDG&E and SMUD have developed a general process for addressing the MDU charging situation which involves coordination with landowners, MDU owners, homeowner's associations and the consumers. The City of San Francisco is identifying MDUs and evaluating ways to provide EVSE, including possible nearby parking sites or car share companies.[67] Fast chargers are also being located at commercial sites in San Francisco and can be used by nearby MDU tenants. Since all multi-tenant residences have 120 V service, there is no need for separate service drops to the PEV charging station for this application, but new lines, conduit and plugs will connect to the station from circuit breaker(s).[68]

In support of MDU charging, the Energy Commission proposes $1 million in grants to provide MDU charging infrastructure and support for solving this complex issue.

Workplace and Fleet Charging

After residential charging, workplace and fleet charging are the second highest funding priority for PEV infrastructure deployment. Consumers are likely to take advantage of the convenience of workplace charging, especially if they do not have access to home charging. Workplace charging can also offer "shoulder" (between on-and off-peak) charging during the morning hours thereby avoiding on-peak charging.[69] In most cases, employers will likely offer free charging to employees as a benefit. Employers gain from having PEV charging available because it can contribute to their Leadership in Energy and Environmental Design (LEED) certification, satisfy employee demand for "green" transportation options, and enhance the company's environmentally conscious (green) image.[70] Most companies view charging as a

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65 October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Residential Panel discussion

66 Electric Transportation Engineering Corporation, Electric Vehicle Charging Infrastructure Deployment Guidelines for Greater San Diego Area, May 2010.

67 Conversation with Bob Hayden, Department of the Environment, San Francisco, January 7, 2011.

68 Plug-In Electric Vehicle Infrastructure Installation Guidelines *Volume 1: Multi-Family Dwellings,* S Chhaya, S., and M Alexander, EPRI 1017682, September 2009

69 October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Workplace and Fleets Panel discussion

70 LEED certification for commercial building owners provides a competitive edge, mitigates risk and attracts tenants. Additional information is available at: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2331

"facilities" decision and are willing to invest in them as employee parking lots are developed rather than retrofit at a higher cost later on. One example of workplace charging is at SAP's Palo Alto campus where the software company is installing 16 charging stations in its parking lot and purchasing 25 PEVs of which 20 will be leased to employees.[71] Other companies such as Google and Dell offer free parking and charging for PEVs powered by solar arrays, an even more attractive zero-emissions option for employees. Workplace charging can be encouraged by education and outreach to companies and facilitated by employee surveys on transportation needs and preferences. In the Bay Area, for example, the Business Council on Climate Change (BC3) will publish an "EV Guide for Businesses", to help Bay Area businesses to create their own EV programs.[72]

Fleets are an excellent fit for the purchase of PEVs and many companies with fleets are investing in PEVs and providing charging infrastructure. Fleet vehicles typically charge in the off-peak hours and travel a regular route. Fleet managers also make purchasing decisions by evaluating total vehicle lifetime costs including maintenance, which is exceptionally low for PEVs. A recent study shows that light-duty PEVs, Class 2-3 trucks in particular such as parcel delivery vans and shuttle buses, will offer the best opportunity for near-term growth in the U.S. commercial fleet sector.[73] General Electric recently committed to purchasing 25, 000 PEVs through 2015 for its Capital Fleet Services global sales force. It also has an agreement with Nissan and Better Place to develop smart grid electricity infrastructure for PEV charging and will deploy its Level 2 "GE WattStation" for commercial and home use.[74] Some car rental companies are actively pursuing the installation of charging infrastructure in locations such as airports for a portion of their fleets in California.

To encourage workplace and fleet charging, the Energy Commission proposes $1 million in grants to support charging infrastructure (with emphasis on photovoltaic charging) and outreach to business and fleet owners.

Commercial, Public and Fast Charging

The deployment of commercial and public charging stations over the next several years will greatly reduce or eliminate consumer "range anxiety" and psychological barriers—both significant hindrances to PEV adoption. Public charging is more important for BEVs as opposed to PHEVs or extended range vehicles (EREVs) such as the Volt. Although most customers will charge at home, they must be assured of readily available chargers within their driving radius and near destinations that extend beyond their vehicle's driving range. As data on public charging infrastructure is collected over the next few years, consumers' behavior and charging requirements will become much better understood.

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71 San Jose Mercury News, "Workplace Charging Stations for Electric Vehicles are the Latest Silicon Valley Perk", December 9, 2010, http://www.mercurynews.com/business/ci_16809939?nclick_check=1

72 Katherine Michonski, Program Manager, Business Council on Climate Change, 1/24/11

73 FleetOwner (January 4, 2011) "Strategic Analysis of the North American and European Electric Truck, Van And Bus Markets", Frost & Sullivan, May 24, 2010.

74 Fleets & Fuels, December 20, 2010.

The ratio of chargers per PEV (for home and public) needed varies from 0.6 to 3.5.[75] The CPUC estimates that one home charging and 0.2 public charging capacity is needed for each vehicle. Nissan, Ford, GM and Chrysler similarly estimate that there is need for one home charger and 0.3 public chargers per vehicle. These ratios are highly speculative and more analysis is needed to understand consumer behavior and charging patterns.

Government support of the initial rollout of PEV public charging infrastructure is necessary to support PEV commercialization until there are sufficient volumes of PEVs to provide a business case for infrastructure providers. Some studies, such as the Tokyo Electric Power Company (TEPCO) study in Japan showed that public or workplace opportunistic charging provided consumers with capacity (or the ability to charge) rather than actual electricity fuel usage. Consumers, therefore, used a greater portion of their battery storage capacity knowing that chargers were available if needed.[76]

It is generally agreed that charging levels should be matched to the purpose of the consumer's destination.[77] For example, airport parking garages may do well with Level 1 charging given the longer periods of parking at airports. Level 2 chargers are appropriate for destinations such as theaters, stores, and coffee shops where vehicles may park for several hours. It is important to maximize the public benefit by leveraging the location of chargers and taking into consideration the breadth of benefit.[78] In Sonoma County, charging sites are often multi-use with overlap between residential, workplace and fleet charging.[79]

Public charging will, however, increase the demand for "on-peak" electricity in most cases. Smart charging will help to coordinate the vehicle's charging and user preferences with the needs of the power grid. Users may receive a lower rate for charging if the utility is allowed to control the timing of the charging to maximize benefits to the grid.[80] Impacts to the grid can also be mitigated by offsetting the increased demand for electricity by improving local efficiency and/or installing photovoltaic systems. The University California at San Diego's Zero Emission Vehicle Project, with $2.5 million from the Energy Commission and additional Department of Energy funds is diverting a portion of its solar and biogas resources to charge a fleet of about 50 new PEVs.[81] This study will establish the technical feasibility of using renewable energy to

75 Based on input at the Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, October 19, 2010. Estimates of this ratio included the following: Electrification Coalition indicates 1.5-3.5 per vehicles through 2015, and .5-1.5 after 2030; RMI indicates 0.6 per vehicle; Bay Area Corridor indicates 0.1-0.2 per vehicle; CPUC indicates 0.2 per vehicle.

76 TEPCO, "Desirable characteristics of public quick charger," http://www.emc-mec.ca/phev/Presentations_en/S12/PHEV09-S12-3_TakafumiAnegawa.pdf

77 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Public Charging Panel, October 19, 2010

78 Ibid

79 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Workplace Charging Panel, October 19, 2010

80 For more information on metering issues, see the CPUC's Alternative Fuel Vehicle Proceeding (R.09-08-009) at: http://www.cpuc.ca.gov/PUC/hottopics/1Energy/090814_ev.htm

81 U.C. San Diego, "The Endgame: Charging of Electric Vehicles with Secure, Domestic, Renewable Energy Resources.

electrify the transportation sector. The Electric Power Research Institute (EPRI), Tennessee Valley Authority (TVA) and Oakridge National Laboratory are testing a solar assisted EV charging station which uses a battery storage system to assess the impact on reliability, analyze EVSE and test advance metering infrastructure. Envision Solar International, Inc. is installing EV charging enabled solar tracking trees at Axion Power International in Pennsylvania.[82] Envision will provide a solar array which incorporates solar tracking into the canopy structure of its parking array. All these developments can provide a solution to the problem of "on-peak" PEV charging. The Energy Commission will consider how to encourage further development of renewable PEV charging infrastructure.

Business models for commercial charging have been evolving as PEVs roll out and the need for charging infrastructure develops. There are some concerns with regard to the long-term economic viability of public charging including the inclusion of maintenance and electricity costs. Various business models are emerging that could support future development of PEV infrastructure without government support. One company, NRG Energy Inc. will be creating a network of public charging stations in Houston, Texas. They hope to expand in the other 13 states that have deregulated electricity markets and will likely use a subscription model to cover the fixed costs of the network.[83] Another company, CCGI plans to bill customers 50 cents per kilowatt hour for public charging, about four times what consumers pay at home for electricity.[84] Ecotality plans to generate revenue from hardware and equipment sales, monthly subscription fees from consumers and fleet owners, advertising at the charging stations and grid services to utilities.[85] The price of subscription fees will likely be in the range of $5 to $10 per month and will ensure a revenue stream for infrastructure providers and charging availability "insurance" for consumers. Some retailers will offer free charging to draw consumers to their stores. Larger companies are entering the market, including General Electric, Schneider Electric and Siemens, all of which have significant economies of scale with regard to equipment sales.

In the absence of a business model, it is likely that public charging infrastructure will require substantial government investment. As viable business models emerge, the need for government support will diminish and expansion of the PEV charging network will be market driven.

In January, 2011 the Energy Commission with the California Air Resources Board conducted an alternative fuels automaker survey and will soon receive the results of expected deployment of PEVs by region through 2015. Pending receipt of the survey, Table C-1 in Appendix C will show the regional demand for Commercial/Public Infrastructure for BEVs. The Level 2 charger demand (Column C) is derived by assuming a ratio of 0.2 public chargers needed per BEV. The

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82 Envision Solar, "Envision Solar Commences EnvisionTrak™ and CleanCharge™ Solar Tree® Installations for Axiom Power International," September 30, 2010, http://www.marketwire.com/press-release/Envision-Solar-Commences-EnvisionTrak-CleanCharge-Solar-Tree-Installations-Axion-Power-1327606.htm

83 Wall Street Journal, "Houston to Get Charging Stations", November 19, 2010

84 "Public EV Charging: Expect to Pay $3.50 an Hour for the Convenience", BNET, Jim Motavalli, 12/8/10

85 Greentech Media, "Will EV Charging Stations be Free?" December 14, 2010, http://www.greentechmedia.com/articles/read/will-ev-charging-stations-be-free/

expected additional Level 2 chargers needed (Column D) is the difference between the existing and planned Level 2 chargers (Column B) and the Level 2 charger demand (Columns B-C). Once the automaker survey results are available the Energy Commission will evaluate the need for funding of public chargers in California depending on market conditions as well as the expected supply and demand balance of PEVs in each region. As a placeholder for estimated funding, the Energy Commission proposes $2.5 million to fill the gaps in California's commercial and public charging infrastructure, especially in areas that have not yet received government subsidies. These funds (assuming 50 percent match) would provide a little over 700 chargers throughout the state.

The availability of fast chargers will increase consumer convenience by reducing the recharge time. Fast chargers have an additional benefit in that widespread deployment would allow automakers the ability to design PEVs that have a lighter, lower cost battery pack designed for daily commute. [86] The ECOtality Blink 480 volt PEV charger is capable of fully recharging a BEV, such as the Nissan Leaf in 15 to 28 minutes. ECOtality is partnering with Best Buy to install 12 Blink chargers in its parking lots, and with BP and Arco to install fast chargers at 45 gas stations.[87] ECOtality will install 60 fast chargers in the San Diego and Los Angeles regions with a grant from the Department of Energy and the California Energy Commission.

In the Bay Area, the Association of Bay Area Governments is partnering with 350Green (through its Energy Commission award) to install up to 19 fast chargers. They are using an Epyon fast charger Level 2 system that allows expansion for up to four charger bollards per one base power unit. Each bollard can accommodate twin fast charge connectors or a dual Level 2 fast charge configuration[88]. The system can also allocate reduced voltage to vehicles and optimize power flow depending on the number of vehicles requiring recharging. 350Green is also partnering with the BAAQMD to install 6 fast chargers at Safeway shopping centers. BAAQMD is also deploying 30 fast chargers in the Bay Area corridor for extended range by local PEV drivers and destination charging for visitors or those passing through. Table 7 summarizes the known planned deployment of 115 fast chargers in California through 2012.

Table 7: Planned Deployment of Fast Chargers in California

Area	Installer	Partner	Number
San Diego and Los Angeles	ECOtality-Blink	DOE/Energy Commission	60
Bay Area	350Green-Epyon	ABAG	19
Bay Area	350Green	BAAQMD	6
Bay Area	ECOtality/Aerovironment	BAAQMD	30
Total			115

Source: California Energy Commission

86 Presentation by David Patterson, Mistubishi Motors, at California Environmental Dialogue Meeting, November, 30, 2010.
87 Los Angeles Times, "BP, Arco, Best Buy to install fast chargers for electric cars", October 13, 2010.
88 Richard Schorske, January 20, 2011.

Fast chargers are being deployed in California in the major PEV regions—in cities and near urban area connectors as well as on highway corridors such as Interstate 5 from Canada to the Mexican border. The first priority of fast charging is at the city-level which can support consumers in multi-dwelling units. [89]From there, the priority extends to connecting urban corridors and then highways.[90] The "West Coast Green Highway" is a three-state initiative involving Washington, Oregon and California which will result in a seamless recharging network along the 1,350 miles of Interstate 5.[91] The majority of ECOtality's fast chargers in the EV Project will be installed along Interstate 5 connecting Vancouver, Canada to the Mexican border. Fast chargers along the west coast artery will greatly reduce consumers' range anxiety on longer trips on various segments of this Interstate. The spacing of chargers along highways is recommended to begin at a minimum of 150 mile intervals, with interval reductions thereafter.[92] The States of Washington and Oregon are planning to install fast chargers at 30 mile intervals partly funded by the EV Project. The Energy Commission proposes $500,000 to co-fund fast chargers along the I-5 corridor in California from the region north of Los Angeles to the Oregon border.[93] In addition, the Energy Commission proposes $500,000 for solar-powered rest stations to facilitate highway corridor charging.

Signage is important for alerting PEV drivers to recharge sites. Standards and best practices for signage need to be funded and developed for effective deployment of charging infrastructure. The Bay Area "Ready, Set, Charge California!" is incorporating this into their local government EV Readiness plan. The Energy Commission proposes supporting signage along highway corridors, possibly through an interagency agreement with Caltrans, for $500,000.

Americans with Disabilities Act (ADA) compliance for PEV charging is an issue that needs further clarification. The State of California's Division of the State Architect has issued "Interim Disabled Access Guidelines for Electric Vehicle Charging Stations" (Policy #97-03). PEV charging stations are required to be accessible because they offer a service to the general public. When PEV charging is coupled with regular parking, the PEV charging is considered the primary service. If there are up to 25 chargers at a site then one accessible charger space is required. Accessible charging spaces are not reserved exclusively for people with disabilities. If there are only three parking spots, one of them must be ADA compliant, although in San Francisco, for example, chargers are allowed to adjoin an ADA compliant parking site. Many communities are attempting to clarify the requirements for ADA PEV parking, and in many cases the requirements are unclear. In order to avoid litigation, communities are expending more resources to ensure the highest possible standards. The Energy Commission supports further clarification of these ADA standards in the State Building Code Sections of Chapter 11 B and 11 C.

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89 October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Corridor Charging Panel discussion

90 Ibid.

91 Automotive News, "Range Anxiety? Not on this Highway", December 6, 2010.

92 October 19, 2010 Joint Energy Commission Staff and Statewide PEV Collaborative PEV Infrastructure Joint Workshop, Corridor Charging Panel discussion

93 The I-5 corridor is about 630 miles from Gorman to the Oregon border (every 30 miles is about 20 chargers at $50,000 per fast charger=$1,000,000)

Table 8: PEV Infrastructure Funding Summary for FY 2011-2012

PEV Regional Readiness	$1 million
Residential PEV Infrastructure Incentives	$1 million
Multi-Dwelling Unit PEV Infrastructure Deployment	$1 million
Workplace and Fleet PEV Infrastructure deployment and outreach	$ 1 million
Commercial/Public/DC Fast PEV Infrastructure deployment and PEV signage	$ 4 million
Total	$ 8 million

Source: California Energy Commission

Light-Duty PEVs

In the past several months, a new generation of PEVs has entered the California light-duty vehicle market. The Nissan Leaf, a BEV with a 100 mile[94] range and a 24 kWh battery, is expected to be purchased by several thousand Californians over the next year or two. The General Motors Chevy Volt, an extended-range plug-in electric vehicle (PHEV-EREV), with a 40 mile all electric range and on-board gasoline generator, is starting to rollout in California. The Tesla Roadster, a BEV with a 245 mile range and 53 kWh battery, has sales of over 1,500 worldwide, and over 160 in California.[95] In 2011, planned BEVs include the BMW ActiveE, Ford Focus, Mistubishi "I", BYD e6, and Coda Sedan. PHEVs planned for 2011 include the Toyota Prius Plug-in Hybrid, Fisker Karma and BYD F3DM. Virtually all manufacturers are planning for greater electrification of their fleet.

There are many forecasts of PEV market penetration in California through 2020 ranging from less than 3 percent of sales to nearly 14 percent of California vehicle sales.[96] The California PEV Collaborative anticipates annual sales of 250,000 PEVs (representing 14.7 percent of projected total annual light-duty vehicle sales) during the "market launch" phase in 2020.[97] The Collaborative also estimates a range of 2 percent to 4 percent PEV market penetration out of a total California light-duty vehicle market of 25 million vehicles. Market penetration will depend on many variables including the success of the initial PEV rollout, future gasoline prices, reduction in battery costs and infrastructure availability. Replacing the existing vehicle fleet takes several decades. For example, conventional hybrid vehicles took 10 years to reach 5.9 percent of new vehicle sales and has reached 1.4 percent penetration into California's fleet.[98],[99]

The California Energy Commission and the Air Resources Board recently conducted an automaker survey of expected annual PEV deployment by California region through 2015. Table C-1 in Appendix C will show the results of this survey.

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94 US EPA LA4 city cycle conducted in laboratory tests

95 California Energy Commission, DMV Analysis of 2009 File Pass.

96 "Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace", California PEV Collaborative, page 12.

97 Ibid, page 29.

98 Ibid.

99 California Energy Commission, DMV Analysis of 2009 File Pass, with the *Total Fuel Use Analysis*

Automakers will continue to pursue the development of PEV technology due to adopted federal Corporate Average Fuel Economy Standards (CAFE) and California Pavley-GHG regulations, securing the benefits of high efficiency, reduced GHG and other criteria emissions, attractive vehicle attributes, and fuel diversity. In addition, the ZEV mandate requires large automakers to produce certain percentages of "pure zero" emission and "near-zero" emission vehicles for sales in California in order to meet California's air quality goals. ARB staff is working on adjustments to the regulation to focus on PHEVs and pure ZEVs in order to incubate these technologies for large scale market penetration. Traditionally, the ZEV regulation has been based on reducing criteria pollutant emissions. Based on a December 2009 hearing the ARB staff has begun regulatory development and will release proposed modifications to the ZEV regulation in fall 2011.[100]

These modifications may include the following:

- Closer alignment of the ZEV regulation requirements with the state's long term air quality and GHG emission reduction goals, specifically for model years 2018 and beyond.
- A renewed and simplified focus on pre-commercial development vehicle technologies (ZEVs and Enhanced AT PZEVs), rather than technologies that already have demonstrated their market potential (PZEV and AT PZEV).
- For model years 2018 and beyond, moving PZEV and AT PZEV vehicle technologies out of the ZEV program and into the Low Emission Vehicle (LEV) program for criteria pollutant and GHG reductions.
- Maintaining only elements of the ZEV regulation that promote the commercialization of ZEV and ZEV-enabling technologies.[101]

The main barrier to the penetration of light-duty PEVs is the high initial vehicle purchase price. Battery costs continue to be the most significant portion of PEV higher costs and are projected to decline with high-volume production and manufacturing efficiencies gained over time. Many forecasts report that the cost of a PEV battery pack will be reduced in half over the next 5 or 10 years.[102] In order to spur sales of PEVs, incentives may be required to offset the price differential between PEVs and gasoline-fueled vehicles.

Incentives

The Air Quality Improvement Program (AQIP) provides up to $50 million per year for Program grants to fund clean vehicles and equipment, air quality research and workforce training. The Clean Vehicle Rebate Project (CVRP) is funded by the AQIP and administered statewide by the California Center for Sustainable Energy (CCSE).[103] A total of up to $5 million was appropriated

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100 Air Resources Board Staff, February 1, 2011

101 Ibid

102 Taking Charge: Establishing California Leadership in the Plug-in Electric Vehicle Marketplace", California PEV Collaborative, page 39.

103 California Center for Sustainable Energy, "Clean Vehicle Rebate Project," https://energycenter.org/index.php/incentive-programs/clean-vehicle-rebate-project

from AQIP in the 2010-2011 funding plan to promote the production and use of zero-emission vehicles, including BEVs, PHEVs, and fuel cell vehicles. Rebates up to $5,000 per light-duty vehicle are available for individuals and business owners on a "first come, first serve" basis who purchase or lease new eligible zero-emission vehicles or PHEVs. Certain zero-emission commercial vehicles are eligible for rebates up to $20,000. The rebate program is expected to be over-subscribed so the Energy Commission has supplemented the CVRP with $2 million for 2011.

Federal tax incentives ranging from $2,500 to $7,500 are available as tax credits for full-function electric-drive vehicles.[104] In order to qualify for a federal tax credit, an electric-drive vehicle must have a battery with a capacity of at least 4 kWh, making the vehicle eligible for the minimum $2,500 credit. Vehicles with a battery capacity of 5 kWh or greater are eligible for an additional $417 of credit for every kWh excess of 4 kWh. Vehicles such as the Nissan Leaf (24 kWh battery capacity) and the Chevrolet Volt (16 kWh battery capacity) will thus be eligible for the maximum $7,500 credit. President Obama recently announced a proposal to convert this tax credit to a rebate program.[105] Also available, although reduced from 2010, is a federal tax credit for 30 percent of the cost of residential (up to $1,000) and commercial (up to $30,000) electric vehicle charging equipment and installations.

Additional PEV incentives include high occupancy vehicle (HOV) lane access through 2015, free parking in many cities, reduced insurance rates by many providers, reserved parking spots with chargers, and the availability of reduced electricity rates. For example, Bay Area residents may obtain a $700 charger rebate, San Joaquin Valley residents have a $3,000 PEV incentive and the City of Riverside residents have access to a $2,000 PEV rebate.[106]

If consumers take into account the vehicle lifetime fuel savings rather than the up-front capital costs of the PEV they would observe additional cost advantages compared to a conventional vehicle today. Table 9 compares the lifetime fuel cost savings of a typical BEV such as the Nissan Leaf with the PHEV Toyota Prius and the counterpart conventional vehicle given varying gasoline and electricity costs. Table 9 shows the fuel savings potential for a 5 or 10 year consumer vehicle ownership. Savings are quite sensitive to the price of gasoline with savings for BEVs almost doubling between $3 per gallon and $5 per gallon levels.

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104 Ibid

105 Department of Energy, "Vice President Biden Announces Plan to Put One Million Advanced Technology Vehicles on the Road by 2015 ," http://www.energy.gov/news/10034.htm

106 California Center for Sustainable Energy, "Plug-in Electric Vehicles," https://energycenter.org/index.php/technical-assistance/transportation/electric-vehicles

Table 9: PEV Versus Conventional Vehicle Fuel Cost Savings Projections[107]

	$2 / gallon gasoline, 10¢/ kWh electricity	$3 / gallon gasoline, 10¢/ kWh electricity	$4 / gallon gasoline, 10¢/ kWh electricity	$5 / gallon gasoline, 15¢/ kWh electricity	$6 / gallon gasoline, 15¢/ kWh electricity
PHEV vs Conventional Savings at 5 years	$1,475	$2,212	$2,949	$3,686	$4,424
BEV vs Conventional Savings at 5 years	$1,497	$2,997	$4,497	$5,246	$6,746
PHEV vs Conventional Savings at 10 years	$2,949	$4,424	$5,898	$7,373	$8,847
BEV vs Conventional Savings at 10 years	$2,994	$5,994	$8,994	$10,491	$13,491

Source: California Energy Commission

A Nissan Leaf's MSRP is $32,780 (or $35,337 including sales tax). After deducting federal tax incentives and the state clean vehicle rebate, the final cost to the consumer is $22,837. This cost compares favorably to a similar conventional vehicle valued at $25,020. In some communities additional incentives will apply. Charging infrastructure is not included in this analysis. A consumer would save $8,994 in fuel savings over 10 years of ownership (at $4 per gallon) resulting in a total cost of $13,753—almost half the price of the comparable conventional vehicle cost of $25,020.[108] For 5 years of ownership a consumer would save $3,084 (at $4 per gallon) resulting in a total cost of $19,753 –still less than the conventional vehicle. An important consideration in setting the appropriate level of incentives is understanding the consumer's approach to vehicle purchasing decisions. The U.C. Davis PHEV Center indicates that consumers do not typically perform such an in-depth life-cycle cost analysis of vehicle costs; rather, they consider the upfront cost of the vehicle.[109]Consumer education regarding the life cycle cost analysis will be essential in order to convey the true benefits and costs of PEV ownership.

Vehicle prices will decline as battery costs are reduced and PEV production volumes increase. Over time there will be less need for government subsidies. It is likely that, in the near term, incentives will still be needed to overcome barriers to the relatively high price of PEVs and PEV charging infrastructure. As the price of gasoline rises and the costs of batteries continue to decline, PEVs will become increasingly attractive.

In 2010-2011, the Energy Commission provided $2 million in Program funds to the ARB's CVRP for light-duty vehicles. The Energy Commission will consider providing funds once again for the rebate program if needed to continue to support the successful rollout of PEVs in California.

107 Staff assumes 9,000 annual miles traveled, BEV at 33.4 kWh/100 miles combined fuel efficiency, PHEV at 59 mpg combined mpg (a 20 percent increase to conventional hybrid) and the base conventional vehicle at 30 mpg.

108 The Nissan Leaf cost is $35,337 including sales tax and the conventional vehicle is the Nissan Altima at $25,020 including sales tax. PEV drivers typically drive less than the average driver at 9,000 miles annually. (Source: Energy Commission Staff).

109 Tom Turrentine, Staff meeting November 2010.

Batteries

Battery Technology

The key issue in the design of a PEV is the selection of the battery. The cost of lithium batteries remains high ($500 - $1,000 per kilowatt-hour) when purchased in relatively small quantities. For the 16 kilowatt-hour battery pack in the Chevy Volt, this equates to around $8,000 - $16,000. Detailed cost modeling done at Argonne National Laboratory shows that – in high production volume (greater than 100,000 packs per year) – original equipment manufacturers should be able to produce batteries in the range of $250 - $400 per kilowatt-hour for all chemistries.

One of the keys to improving the performance and reducing the costs of PEVs is increasing the amount of energy that can be stored in a battery given its size (energy density); and increasing the amount of power the battery can deliver (power density). A recent Energy Commission report presented test data on the performance of various battery chemistries for use in PHEVs. The data shows that for all lithium-ion chemistries tested, power density can be increased but not without sacrificing the battery's energy density and cycle life — and vice versa. As a result, battery pack sizes must either be increased or more expensive materials used to meet both the power and energy storage requirements of the vehicle.

It has been recognized for a number of years that combining batteries and ultracapacitors can offer advantages in hybrid electric vehicles. Ultracapacitors can deliver very high power and respond in fractions of a second, but have limited storage capacity. Batteries have lower power capability, but with high energy density can store relatively large amounts of energy. The combination of batteries and ultracapacitors can deliver high power and high energy and is ideal for PEVs in terms of extending the battery life and downsizing the battery pack. The PH&EV Research Center modeled various combinations of advanced lithium batteries and ultracapacitors in PHEVs and compared their performance with batteries alone. In all respects, vehicle performance was improved using ultracapacitors for all the batteries studied. The simulation results also indicate that using ultracapacitors, batteries with a wide range of power characteristics can be used in PEVs without sacrificing vehicle performance and subjecting the batteries to high stress that may shorten their life.

As research and development continues to increase the energy density of lithium batteries, ultracapacitors will likely be needed to meet the power demands of PEVs. Currently the cost of ultracapacitors remains high, due mostly to high material and high manufacturing cost.

Battery Reuse

There is considerable interest and potential for the reuse of vehicle batteries for applications after they are no longer suitable for use in vehicles. Vehicle batteries must provide a minimum level of power to the vehicle's electric motors. Although the batteries are no longer usable in the vehicle ("spent") when they drop to 70-80 percent of their power capabilities, such batteries could have significant life in other applications that have less demanding energy and power requirements. Repurposing vehicle batteries in second use applications would increase their salvage value and extend their useful life. In particular, the utilities may find value for repurposed vehicle batteries as storage devices for intermittent renewables, particularly nighttime wind power, and delivery devices for peak needs, especially if such devices help to avoid building new power plants. Such devices could be distributed in household garages and basements or aggregated into power centers and be used to provide various services to the grid, the utility, and the electricity customers.

A recent Energy Commission report estimates that a repurposed 6 kilowatt-hour vehicle battery pack — enough capacity to provide a PHEV with approximately 15 miles of all-electric range — could generate net revenue streams of over $1,000 per year for grid ancillary services. These revenue streams could significantly decrease the monthly lease payment for the vehicle battery pack. As vehicle battery production ramps up and battery costs drop, revenues generated from second-use applications could fully cover – and potentially exceed — the monthly lease payments.

There are several ways in which the reuse of batteries could be utilized to reduce the cost of PEVs either initially or over time as the vehicle is used. In any case, the purchasers of PEVs would have to benefit from the value of second-use of batteries. This could be done by subtracting some fraction of the sale price of the reused batteries from the initial cost of the new plug-in vehicle batteries. This could be done most easily if the same company owned the batteries over their complete life, including second-use. Another approach is for the PEV owner to lease the batteries or pay for the batteries as they use electricity stored in the batteries. In either case, the cost of the batteries would be paid over their lifetime, significantly reducing the initial cost of the PEV.

To promote the development of the second-use vehicle battery market, the Energy Commission is identifying and evaluating potential reuse strategies. In 2010, the Energy Commission — working with the Plug-in Hybrid and Electric Vehicle (PH&EV) Research Center at UC Davis — awarded funding to the California Center for Sustainable Energy (CCSE) to begin developing the home energy storage appliance (HESA). This device will use "spent" vehicle batteries, be suitable for placement in garages, and provide ancillary services to the electricity grid. Since the Energy Commission's initial award, the U.S. Department of Energy has awarded an additional $700,000 in funding over a longer period to CCSE and the PH&EV Research Center to conduct additional work on second use applications for lithium batteries.

The Energy Commission has tasked the PH&EV Research Center to further develop the HESA and evaluate new ways to use "spent" vehicle batteries in grid storage applications. This will include developing and testing energy storage devices, like the HESA, in other smart-grid applications including industrial sites, shopping malls, large buildings, and public charging stations. In particular, the PH&EV Research Center will evaluate methods to integrate these storage devices in applications that have distributed generation resources such as solar photovoltaic systems.

Battery Recycling

The question of recycling the battery is something that must be addressed before significant quantities of vehicle batteries are produced. Large scale recycling has the potential to not only reduce the environmental footprint of lithium vehicle batteries, but also reduce their high costs if battery materials are able to be reused. Currently, there is not yet the capacity (or the need) for recycling large lithium vehicle batteries. In 2009, the U.S. Department of Energy awarded $9.5 million to a company in California to build the nation's first recycling facility for lithium vehicle batteries. As the PEV market grows, additional battery recycling centers will need to be built. In addition, some system of requiring that the batteries be recycled will need to be established. The Energy Commission has tasked the PH&EV Research Center to discover the full cost of disposal and identify potential ways to reuse battery materials; and assess the potential for large scale recycling of lithium vehicle batteries.

Table 10: Plug-In Electric Vehicle Funding Allocation

PEV Readiness and Charging Infrastructure	$8 million
Medium- and Heavy-Duty Advanced Vehicle Technology Demonstration	*See Medium- and Heavy-Duty Vehicles Section*
Total	$8 million

Source: California Energy Commission

Hydrogen

Hydrogen can be derived from a number of sources, including natural gas, biomethane, electricity from fossil fuels, and electricity from renewable resources. Hydrogen produced through steam methane reformation and used in an FCV can reduce GHG emissions by 56 percent[110] and petroleum consumption by 99.7 percent when compared to California's reformed gasoline used in a conventional vehicle. Like BEVs, FCVs produce no tailpipe emissions; however, unlike with BEVs, there are no energy storage issues with FCVs. They store the hydrogen fuel in on-board pressure tanks. Today's FCVs hold enough hydrogen in on-board tanks that driving ranges of 250 miles or more are possible in everyday use. Refueling is relatively quick with about 3-5 minutes per fill (for 700bar stations and newer vehicles that can be fueled at the higher pressure).

However, a major barrier for this fuel and the vehicle technologies using hydrogen remains the economy and high cost at numerous levels. Vehicle production and fueling infrastructure are still at a pre-commercial stage, where industry cannot take advantage of economies of scale benefits that come with commercial production volumes. However, there are indicators that cost is decreasing on both the vehicle and fuel infrastructure side. One OEM has mentioned that FCVs are now headed below the $100,000 mark and several OEMs have plans to lease vehicles to the public at somewhat affordable lease rates. The Energy Commission has also seen the cost per fueling station decrease from $3-$6 million to $1-$2.5 million over only a few years.[111] This was made possible due to modular designs and strategically designed fuel production and distribution models.

Fuel Conversion and Production

Steam methane reformation

The most common method for producing hydrogen is through large-scale steam methane reforming (SMR) facilities, where methane from natural gas (or biomethane) is broken down in a reaction with high temperature steam. The resulting products are hydrogen, and carbon dioxide which is released into the atmosphere. The hydrogen is purified and compressed for storage and transport. Large-scale SMR units are relatively energy-intensive installations that allow for a comparably low-cost production per kilogram (kg) of hydrogen. The process energy is generated by the combustion of the same natural gas that serves as the feedstock and some electric power. The vast majority of hydrogen today is produced for various non-transportation purposes, such as in oil refineries, the chemical industry (methanol, ammonia, hydrochloric acid), in the food industry (oil/fat hydrogenation), or as a shielding gas for welding. Less than one percent of hydrogen produced today is used as a transportation fuel.

One major in-state provider, Air Products, produces its hydrogen in a large-scale industrial installation in Southern California, using natural gas derived from the pipeline. Although hydrogen is produced and traded in large quantities as an everyday industrial gas and can be

110 LCFS/GREET model, Pathway: 100 percent natural gas SMR, fuel used in an FCV

111 Based on information from proposals received by the Energy commission under PON-09-608.

produced at moderate cost today (at approximately $5-10 per kg), it has not yet reached cost-competitiveness with petroleum fuels on an energy-equivalent basis. [112]

Hydrogen as a transportation fuel furthermore requires higher purity levels than hydrogen for industrial uses because fuel cells stack membranes are sensitive to impurities. Purification, mostly from byproduct gases, is typically performed by pressure swing adsorption (PSA), an effective but costly technology that adds to the capital and operation/maintenance cost for SMR facilities.

Early hydrogen fueling station sites were equipped with on-site hydrogen production units, many using SMR technology, others using electrolysis. Energy Commission observations suggest that on-site production often comes with relatively high maintenance and capital cost, and can only produce relatively small amounts of hydrogen fuel. However, it can present significant potential for renewable hydrogen production if paired with a local source of biomethane or renewable power for example from photovoltaic systems.

SB 1505 (Lowenthal, Chapter 877, Statutes of 2006) requires that all hydrogen used for transportation fuel in the state must be at least 33.3 percent from renewable sources. The ARB, which administers this mandate, has not yet fully established the requirement and is currently working on establishing regulations to clarify details of the mandate. For example, the ARB is considering a temporary reduction of the 33.3 percent requirement to 20 percent, to account for the lack of availability of renewable hydrogen or the feedstocks necessary for its renewable production during the early years of its implementation. In the case of steam methane reformation, these renewable resources are likely to depend significantly on the use of biomethane. Natural gas used in the SMR process can easily be substituted for biomethane to reach a renewable hydrogen product. Another aspect that ARB is currently investigating for the regulations is how credits for renewable power and renewable Biomethane will be applicable to the mandate and what kind of tracking mechanisms can be used for these two compliance pathways. A July board meeting has been tentatively scheduled for the approval of the rulemaking.

Electrolysis

Electrolysis consists of water molecules being cracked with electric power into oxygen and hydrogen. The oxygen is released into the atmosphere and the hydrogen captured and compressed for storage. From 2002 to 2007, a few experimental and demonstration electrolysis fueling stations were built in California, funded by consortia of industry, federal, state and local agencies. Some of these stations utilized electrolysis to produce hydrogen on-site. However, Energy Commission observations suggest that on-site electrolysis comes with relatively high maintenance and capital costs, and can only produce relatively small amounts of hydrogen fuel over time. This suggests that on-site may not be the most cost-effective option today. Electrolysis possesses significant potential for renewable hydrogen production, particularly when the electricity comes from renewable sources such as photovoltaic arrays. In recent years, California has seen a decline of on-site production fueling stations in favor distributed models with central production. Centralized production is being dominated by SMR due to the high cost that large-scale central electrolyzers would entail while producing only moderate amounts

112 One kg of hydrogen contains approximately the energy equivalent to one gallon of gasoline

of hydrogen. Today, central SMR seems to be favored over on-site production. The general trend moving away from electrolyzers can also be observed in the recent competitive solicitation issued by the Energy Commission in Fall 2010, in which no on-site electrolyzers were proposed.

The same SB 1505 requirements for renewable hydrogen that were discussed under "Steam Methane Reformation" apply equally to electrolysis. Given that electrolysis does not utilize methane, renewable natural gas is unlikely to play a significant role in ensuring renewable hydrogen from electrolysis. Pairing electrolysis facilities with distributed renewable electricity generation is a much more likely avenue for compliance. Among the items the ARB is investigating prior to establishing its requirements is whether and how renewable electricity will be applied to this mandate as a feedstock.

Upstream Fuel Infrastructure

Today, centralized hydrogen production with truck-based delivery to the fueling stations is more cost-competitive than on-site production, particularly on a cost per kg basis. This approach allows large amounts of fuel to be produced at relatively low cost, and allows for significantly reducing the cost for each fueling station because much equipment is only at a single central filling station, and not at each fueling station. On-site production has proven to be a relatively high-cost option, in part because of the high maintenance that on-site SMR units require and also given the relatively small amounts of fuel they produce.

There are multiple pathways for connecting centralized hydrogen production with fuel dispensing stations. The first of these pathways has been developed by in-state hydrogen provider Air Products. The hydrogen is produced in a centralized facility, purified by pressure swing adsorption, and then compressed and filled into tube trailers at a central filling terminal located at that same facility. The tube trailers serve as means of transportation and on-site storage at each fueling station. The trailer is connected to the on-site equipment, including compressors (for increasing the fuel transport pressure to the dispensing pressure) and the dispenser to allow fueling of FCVs. Once depleted of hydrogen, a trailer is replaced with a newly-filled trailer.

Another in-state provider of hydrogen, Linde, has developed a different delivery system for its hydrogen. Their process produces liquefied hydrogen which is filled into tanker trucks. These trucks deliver the hydrogen to fueling stations where the liquid hydrogen is pumped into a large on-site tank. Liquid hydrogen is super-cooled and therefore these tanks are built with thick, double steel walls. The equipment at the fueling station includes vaporizers, which turn the liquid hydrogen fuel into its gaseous state on-demand. Intermittent storage in tube stacks assures an immediately available supply of fuel at the necessary pressure. Compressors regulate the availability and correct pressures of fuel for dispensing.

Fueling stations with hydrogen production and fueling configurations located on-site have been demonstrated over the past decade. These stations required no upstream infrastructure, as the production of hydrogen is co-located with fuel dispensing. However, both electrolyzer and SMR on-site systems have significant downsides. They currently only produce small quantities of hydrogen and they are very cost-intensive and known to be relatively high maintenance technologies.[113] Given today's modern requirements for capacity and peak fueling, an on-site SMR unit would need to be very large, which may not necessarily be feasible at existing gasoline stations due to lack of space. [114] In recent years, California has seen a decline of on-site production fueling stations in favor distributed models with central production. This can also be seen in the recent competitive solicitation issued by the Energy Commission in fall 2010, in which no proposals with on-site production were submitted.

Localized Fuel Retail Infrastructure

Private fleet fueling infrastructure

Several OEMs in California maintain and operate private hydrogen fueling stations to supply their own demonstration fleets of FCVs. These dispensing installations possess small capacities, and are often located on the premises of OEM testing and development facilities; as such, they are typically inaccessible by FCVs from other OEMs. Transit authorities' hydrogen stations are currently inaccessible in the same way, however, the first one that will be different is AC Transit's Emeryville station that will allow public access "outside the fence" to fuel FCVs in addition to FCBs "inside the fence".

The Energy Commission has emphasized that these exclusionary, private stations do not contribute to the cooperation necessary to build a viable hydrogen station network that will address near term consumer demand. Furthermore, the vehicle owners will soon be individual consumers so fleet/private fueling generates a big fuel demand gap. Therefore, the Energy Commission, in its 2010 hydrogen infrastructure solicitation (PON-09-608), required that proposed stations be publicly accessible without prohibitive user agreements.

Some projects in the past and present use mobile fueling vehicles in order to supply location-independent demonstrations and fleets. This will likely continue to be an option, to bridge temporary gaps in fuel supply that may arise from lack of fueling stations in some areas of the state. However, as automakers begin deploying FCVs in the hundreds and thousands, they are not likely to be a significant part of hydrogen refueling strategy.

Public hydrogen fueling infrastructure

As part of implementing the Program, the California Energy Commission is providing funding to projects that support hydrogen fueling infrastructure driven by the fuel demand of pre-commercial fuel cell vehicles (FCV) deployed by automakers in California. Subsequent to the 2008-2010 Investment Plan, the Energy Commission provided $22 million for the establishment of hydrogen infrastructure based on the information available from public agencies, public and private organizations, and other stakeholders.

Based on this information, the Energy Commission released a competitive solicitation in June 2010. Out of the proposals for 16 stations received, a total of 11 stations (total $15.6 million in Energy Commission funding) were proposed for award. Eight of the stations represent new installations, and three are upgrades. Once awards are finalized and grant agreements are

113 Research still ongoing – Comparative cost data, H2 quantitative data and "high maintenance" related sources etc. will be added here later as much as available

114 Peak Fueling is defined by SAE as three consecutive hydrogen fuel fills totaling 20 Kg within one hour

developed, work will begin on constructing the stations. The stations are strategically located in areas where automakers have committed to significant numbers of fuel cell vehicle deployments over the next three years, with nine of the stations located in the greater Los Angeles area, one near San Francisco International Airport, and one in the Sacramento area.

One key requirement was that the proposed stations had to be backed with location-specific, automaker endorsements for vehicle deployments, which allowed the Energy Commission to match supply to demand. All of the funded stations have a minimum of 100 kg/day capacity to ensure ample fuel supply for California's hydrogen FCV drivers.

In order to establish a baseline of existing publicly accessible hydrogen fueling stations in California, an agreement was successfully executed with the Energy Commission's technical support contractor to perform a comprehensive assessment of all publicly accessible stations in California. In 2010, the report found that of twelve publicly accessible fueling stations in California, eight stations are operating (two are transit stations), and the other four offer limited operation and public accessibility.

It is anticipated that five hydrogen fueling stations will be completed and come online in 2011. These stations, co-funded through ARB during their 2008-2009 solicitations, are all located in Southern California. Another eleven stations are expected to be completed under Energy Commission funding by late 2012. The 2010-11 Investment Plan included up to $13 million allocation for hydrogen fueling stations. Based on the 2010 solicitation, the Energy Commission anticipates that 7-9 additional stations can be funded.

There are two transit hubs in California that own and operate hydrogen-operated buses. SunLine in Thousand Palms and AC Transit in Oakland (together with a consortium of five transit agencies around the Bay Area) both also operate hydrogen fueling stations. Sun Line has one bus fueling stations and AC Transit's old station in Oakland is closed and will be replaced by a new station in the same location (Co-funded by local, state and federal sources). An additional station is being built by AC Transit in Emeryville.

Medium- and heavy-duty applications and other projects use mobile fueling vehicles in order to supply location-independent demonstrations and fleets. This will likely continue to be an option, also to bridge temporary gaps in fuel supply for such projects that may arise from lack of fueling stations in some areas of the state. Mobile fuelers are skid-mounted with a tube trailer. These can be easily moved for a great level of flexibility of location.

Needs Analysis

The Energy Commission is committed to fund projects that support the fueling need for developing hydrogen fueling infrastructure driven by the fueling demand for pre-commercial fuel cell vehicles (FCV) deployed by automakers in California. In June 2010, the Energy Commission released a solicitation for hydrogen fueling stations, resulting in $15.7 million in proposed funding awards for a total of eleven stations; eight new and three upgrades to existing facilities. The stations are strategically located in areas where automakers have committed to significant numbers of fuel cell vehicle deployments over the next three years, with nine of the stations in Southern California, and two in Northern California.

This solicitation incorporated automotive and hydrogen producer industry input in its design to achieve the highest cost-efficiency. A key requirement was that the proposed stations had to be backed with location-specific, automaker endorsements for vehicle deployments, which allowed the Energy Commission to match demand with supply.

The December 2010 OEM survey for FCV commitment numbers resulted in responses from seven OEMs. Table 11 compares these numbers to the 2009 survey results. Although the new numbers are between 23 percent and 44 percent lower than the previous year's (and 11 percent higher for the long-term range 2015-17), the 2012 values are within range of the commitments presented by automakers in letters of commitment in proposals for the 2010 hydrogen fueling station solicitation.

Table 11: 2009 and 2010 Fuel Cell Vehicle Survey

	2011	2012	2013	2014	2015-17
2009 Survey	330	495	769	1839	47,800
2010 Survey	253	312	430	1389	53,000
Percent Change	-23	-37	-44	-24	11

Source: California Energy Commission

The geographical distribution of OEM vehicle commitment numbers shows that OEMs are concentrating on more on the clusters where the Energy Commission is proposing awards for fueling stations (e.g. Orange County, Torrance). Other locations, such as Burbank, are not currently considered key locations by OEMs for their FCV deployments.

A thorough analysis and comparison with the 2009-10 gap analysis shows that the eleven stations proposed for funding by the Energy Commission under the Program would cover the fuel demand until 2014. It further shows that a supply shortage would only arise in Orange County and the San Francisco East Bay by 2014 if the ARB-funded stations that will likely come online in 2011 should cease operation after their agreement life expires.

CALSTART, in December 2010, was awarded $10 million from the Federal Transit Administration for two projects that will lead to the development of lower cost and more durable zero emission fuel cell buses. Fuel cell buses improve urban air quality because they produce zero tailpipe emissions while also producing far fewer greenhouse gas pollutants. The funding will primarily be used to help leading fuel cell manufacturers improve the performance of and lower the costs of their bus technology. The Energy Commission intends to support this program to help develop Southern California Transit hydrogen fueling infrastructure to supply these buses with hydrogen transportation fuel. The Energy Commission will allocate $3 million in funding for hydrogen transit fueling infrastructure for fiscal year 2011-2012.

Studies to Support Strategic Infrastructure Planning

The Energy Commission is entering into an interagency agreement with the University of California that will enhance the Spatially and Temporally Resolved Energy and Environmental Tool (STREET). This multi-year project will expand an existing model to all of California (previously only the South Coast Air Basin) and to all alternative fuels. It represents UC Irvine's modeling approach for identifying, analyzing, and understanding the interplay between GHG, criteria pollutant emissions, water usage, etc. generated from displacing existing transportation fuels and technologies. The work is used to predict environmental and resource usage impacts of current and proposed transportation infrastructure scenarios. Current and past funding sources for the APEP include U.S. DOE, Toyota, Air Products, Honda, Nissan, ARB, and the Energy Commission. The Energy Commission is also pursuing an agreement with NREL's Center for Transportation Technologies Systems to provide technical support services for the program, in particular, market assessments of advanced vehicle fuels and technologies, fuels research, criteria, and GHG emissions characterization and improvement, biofuels production and use, hydrogen vehicle technology evaluation and infrastructure needs, and the ongoing work the laboratory is presently engaged in regarding scenario planning to achieve climate change, petroleum reduction, and air quality goals in the state.

Recent Improvements to Fueling Infrastructure

The Energy Commission has assessed that earlier hydrogen fueling stations were built at a cost of approximately $3-6 million per station. This relatively high capital cost has been identified as one of the major hurdles in establishing a viable hydrogen fueling network in California. In order to address this and encourage equipment providers and project proposers to take steps in lowering the cost, the 2010 solicitation used a "sliding scale" performance incentive mechanism. This tool rewarded projects with a higher share of match funding the lower the overall price tag for each single fueling station was. The successful outcome of the incentive lowered the price range for the proposed stations to about $2-3 million for each station. In general, there are signs of decreasing cost for stations as the industry develops new, innovative production, distribution, and retail supply strategies that are more cost efficient. For instance, more modular, "all in one container" designs as well as shifting some equipment to a central production/filling location instead of at each site can contribute to these decreases.

A similar performance incentive was included in that same solicitation that rewarded project proposals if their station could be built and brought on line in 18 months or less. This time frame is considerably less than what has been observed in the past to build such stations. Shorter construction times reduce costs, and allow the station to reach utility sooner. It also allows for better infrastructure planning in the long run. Much experience has been gained during recent years regarding the permitting processes for hydrogen fueling stations. Local government permitting agencies and fire officials in cities of prospective sites are slowly getting to know the technology better and their understanding and familiarity have greatly helped accelerate and facilitate these permitting processes. Automakers and station builders have done their share in working with local representatives to improve this. Permitting times as short as four to eight months have been reported in some cases.

The solicitation also included a set of minimum requirements. The Energy Commission included a requirement that called for projects to be "public access" and present a "retail-like" experience. This was done in order to improve the experimental character of many current stations to a more pre-commercial scenario where users had unrestricted drive-up access (e.g. no gates, fences, guards, key codes or alike) to the fueling dispenser(s). In addition, the design of the station was supposed to offer most attributes that a typical conventional fueling station offers (e.g. good lighting, signage, simple user-interface etc.).

Fuel quality standards

Through a contract with California Department of Food and Agriculture's (CDFA) Division of Measurement Standards (DMS), the Energy Commission is funding activities to develop and establish retail fuel quality standards for hydrogen. For hydrogen, a sound infrastructure is one of the biggest challenges before mass utilization of hydrogen vehicles can take place. Offering high quality fuel will be a key component in the successful deployment of commercial grade hydrogen fuel. Hydrogen fuel must be of the highest quality to provide the best possible vehicle performance, not damage fuel cells, and reward car manufacturers for their investment into new technology. Establishing testing procedures and quality standards for commercially available gaseous hydrogen as a transportation fuel is a critical first step in the development of a fair and competitive marketplace in the California hydrogen infrastructure. This will enhance consumer protection, foster fair competition, and facilitate economic growth and trade. CDFA/DMS will adopt regulations as necessary to incorporate any changes to its hydrogen standards or to clarify existing statute or code.

In order to further support hydrogen infrastructure development, the Energy Commission funded the California Department of Food and Agriculture's Division of Measurement Standards to develop retail fuel quality standards for hydrogen and a type approval for measuring/ and dispensing hydrogen for sale in California.[115] These efforts will help remove major obstacles to commercialization of hydrogen as a transportation fuel and aid in developing the fueling infrastructure.

The same contract will allow CDFA/DMS to prepare the groundwork to establish a standard for the commercial measurement of gaseous hydrogen for vehicles and other refueling applications. This type approval is strongly needed, as there is currently no regulatory standard established in California for equipment to measure hydrogen transportation fuel for sale on a per-kg basis. These efforts will help remove major obstacles to commercialization of hydrogen as a transportation fuel and aid in developing the fueling infrastructure.

Light-Duty Fuel Cell Vehicles

The benefits of high efficiency, reduced GHG and other criteria emissions, fuel source diversity, and attractive vehicle attributes are the primary motivations for automakers pursuing fuel cell and other electric drive vehicle technologies. In addition, state policy including the ZEV mandate is driving the timing of industry investments. While the current volumes are low, FCVs are expected to move from the current demonstration stage to early commercial volumes within the decade. A joint ARB/Energy Commission survey of eight automakers was conducted in 2009. The survey was conducted again in 2010, and the aggregated results can be seen in Appendix B.

Fuel cell vehicles are the most prevalent vehicle technology that uses hydrogen as a transportation fuel. FCVs produce electricity on board by forcing the hydrogen through a stack of membranes, where it reacts with the oxygen from the air and produces electric power. The vehicle is then powered by electric propulsion using this power. Temporary buffer storage of

115 A "type approval" is granted to a product that meets a minimum set of regulatory, technical and safety requirements. Generally, type approval is required before a product is allowed to be sold in a particular country.

the electric power aids in increasing efficiency and drivability, thus some FCV are battery-assisted or a type of hybrids. Hydrogen is stored in on-board, pressurized tanks.

Several OEM have FCVs readily available, and are planning to build these for lease to selected customers. Toyota announced on January 13, 2011 that it is on schedule to sell hydrogen cars by 2015 or sooner in California, Japan and Germany. They also announced that they have cut the cost to make hydrogen vehicles to less than $100,000 and aims to cut that cost in half (to $50,000) by the time sales begin.[116]

The ZEV mandate is significantly driving the timing of industry investments. While the volumes are currently low, FCVs are expected to move from the current demonstration stage to early commercial volumes within the next decade. ARB expects a number of vehicles could be rolled out under ZEV compliance path options and under the LCFS base case scenario. The ARB is evaluating a number of approaches to provide policy incentives to energy companies who invest in ultra-low-carbon fuels including hydrogen. This includes, for example, the use of credit multipliers under the LCFS or the Clean Fuels Outlet as part of the ZEV program.

Hydrogen internal combustion engine vehicles (HICEV) are vehicles that combust hydrogen as a gaseous fuel in an internal combustion reciprocating engine similar to a gasoline or natural gas propelled vehicle. Unlike the FCV, this technology does not use electric power, but it does include on-board pressurized fuel storage of hydrogen. HICEVs have been tested in California for years, mostly in the five cities project in Southern California where originally 25 Toyota Priuses were converted to HICEV. While some of these cars are still used today and other OEMs have experimented with HICEV as well, the technology has been observed as relatively high maintenance and low-range. Accordingly, it does not seem like HICEV will become the prevalent hydrogen propulsion technology in the near future.

Stationary Applications

A recent report for the US DOE identified at least two near-term markets for non-road use of hydrogen fuel cells: forklifts in warehousing and distribution centers and airport ground support equipment (which include certain classes of forklifts). Fuel cell forklifts are considered to have near-term market potential because they provide zero emission operation, eliminate the need for battery storage space, allow rapid refueling, and do not lose power during operation. The ability to rapidly refuel is especially attractive for multi-shift applications. Indoor and outdoor air quality concerns are another important reason for preferring fuel cell forklifts over combustion engine forklifts in the workplace. A number of material handling site owners have already indicated a willingness to support such applications. The U.S. Department of Defense, through the Defense Logistics Agency, has a large fuel cell forklift demonstration program underway at distribution depots throughout the country.

Argonne National Laboratory has estimated that about 50,000 battery electric forklifts have been sold each year from 2005 to 2007 representing a large market potential for this emerging technology. In some cases, infrastructure to serve non-road applications could also adequately

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116 Bloomberg, "Toyota Advances Hydrogen Fuel Cell Plans Amid Industry's Battery-Car Push," http://www.bloomberg.com/news/2011-01-13/toyota-advances-hydrogen-plans-amid-industry-s-battery-car-push.html

serve light-duty vehicle applications. Finding such locations may be a challenge but would offer opportunities to leverage funding and increase capacity for multiple use stations.

The Energy Commission acknowledges the importance of non-road applications and their potential to further fuel cell technology. In its recent solicitation for hydrogen fueling infrastructure, the Energy Commission did not exclude non-road fueling stations. Such stations were eligible as long as a proposer could present a project that combined non-road fueling with FCV fueling dispenser installations in a multi-use project (and adhere to all other minimum requirements of the solicitation). No such project proposals were received.

Bridging Technologies

Related "bridging" technologies are being developed for hydrogen. For example, blending up to 30 percent hydrogen with natural gas and hydrogen-compressed natural gas (H/CNG) fuels reduces emission and improves operational results in trucks, buses, and vans. Hydrogen-fueled internal combustion engines (HICE) offer another bridging technology with the potential to reduce GHG and criteria emissions although the lower efficiency of combustion engines relative to fuel cells reduces their benefits. Depending on commercialized FCV costs, HICE may be a viable transition option from existing conventional vehicle technology.

Table 12: Hydrogen Funding Allocation

Hydrogen Transit Infrastructure	$3 million
Medium- and Heavy-Duty Advanced Vehicle Technology Demonstration	*See Medium- and Heavy-Duty Vehicles Section*
Total	$3 Million

Source: California Energy Commission

Natural Gas

Given its abundant existing supply and distribution infrastructure, natural gas represents a strong opportunity to reduce petroleum dependence and GHG emissions within California. Vehicles operating on compressed natural gas (CNG) reduce petroleum fuel use by 99 percent, and reduce GHG emissions by 29 percent relative to gasoline and by 21 percent relative to diesel on a full fuel cycle basis (although some criteria pollutants can be higher than for new diesel vehicle counterparts).[117] Due to the clean burning properties of natural gas, natural gas vehicles (NGVs) have also been historically favored as a means of reducing criteria air pollutants. Furthermore, because the high pressure fuel system is sealed, there are little or no evaporative emissions during fueling and use (although there can be some gas release during refueling).

Natural gas is competitively priced with gasoline, typically retailing 5 percent to 20 percent lower than gasoline, which also reflects any associated infrastructure costs.[118] Natural gas typically retails for 3 percent more to 26 percent less on a diesel-energy-equivalent bias. However, the current average lower fuel economy of NGV's may offset CNG's fuel price advantage.[119]

Natural Gas Supply

Natural gas is primarily used as an energy source for space heating and water heating, and is a significant resource in the production of California's electricity. The transportation sector accounts for less than one percent of natural gas consumption within the U.S. and California.[120] Estimates of natural gas reserves are expected to increase, as new technologies for extraction are developed and new reserves are located. The market price of natural gas, which was subject to significant periods of volatility in the previous decade, is expected to stabilize at a level that is significantly competitive with petroleum-derived fuels.[121]

Roughly 87 percent of California's natural gas supply is delivered from outside the state, via five interstate gas pipelines. The source of this LNG is likely to be foreign sources, generally located in Southeast Asia, and transported via tanker ship.[122] The liquefied natural gas (LNG) facility located in Costa Azul, Mexico, is capable of processing up to one billion cubic feet per day and could provide additional supply to the California natural gas market. However, at the present time none of the LNG imported into the United States is allotted for transportation fuel

117 Staff Comparison of 2007 and 2009 MY heavy-duty engine ARB Executive Orders.

118 Energy Commission Staff Analysis of statewide, retail fuel prices. CNG has 10 percent-to-20 percent lower prices per gasoline gallon equivalent, last-year average and 10-year average respectively. (A 5 percent fuel economy loss is applied to the CNG price.)

119 Energy Commission Staff Analysis of statewide, retail fuel prices. CNG has -3 percent-to-23 percent lower prices per diesel gallon equivalent, last-year average and 10-year average respectively.

120 U.S. Energy Information Administration, *California Natural Gas Summary*, http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_SCA_a.htm.

121 U.S. Energy Information Administration, *Forecasts and Analysis of Energy Data*, http://www.eia.gov/oiaf/forecasting.html.

122 California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF

because of the economics. However, some U.S. refineries are considering producing LNG for export.[123]

The expansion of natural gas supply to include shale sources has the opportunity to provide an abundance of natural gas, keeping prices moderate. Estimates of shale gas reserves range from 842 trillion cubic feet (TCF) to 2,240 trillion cubic feet (TCF)[124,125]. The lower estimate gives a 37 year supply at the present consumption rates. By mid-2008, shale production represented almost 10 percent of production from the lower 48 states, and the Natural Gas Supply association believes that production from the shales "…could double in the next 10 years and provide one-quarter of the nation's natural gas supply."[126]

A process known as hydraulic fracturing (HF), used by gas producers, is a method of accessing natural gas from sources such as coalbeds and shale gas formations. This process involves creating fractures in underground formations to allow natural gas to flow. Water and sand are pumped in to the rock formations under high pressure to create fractures. These newly created fractures are then "propped" open by the sand, which allows the natural gas to flow into the wellbore and be collected at the surface.[127] However, there are environmental risks associated with the use of hydraulic fracturing process in the recovery of shale gas. Hydraulic fracturing uses hundreds of thousands of gallons of water treated with chemicals. The volume of chemicals in this water is a source of concern and debate.[128]

Natural Gas Processing

In order to be transported via pipeline, all natural gas must conform to pipeline standards and be treated to remove solids, free liquids and reduce water vapor content to acceptable levels. The treatment process also separates the heavier hydrocarbon components (ethane, propane, and butanes) that can derive higher economic value in the petrochemical feedstock market. Once the natural gas has been sufficiently purified, it enters interstate and intrastate commerce, and becomes a fungible commodity.

In addition to its use in natural gas vehicles, natural gas can also be used as an input fuel for the production of other alternative fuels. In particular, natural gas can be converted directly into hydrogen via steam methane reforming. (For more details on this process, see the "Steam Methane Reforming" discussion.) Moreover, methane (whether natural gas or biomethane) can be blended with hydrogen. The advantages of combining natural gas and hydrogen include improved combustion efficiency, and significantly smaller energy requirements for ignition.

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123 Phone conservation with Michael L. Eaves, Clean Energy on January 6, 2011

124 January 9, 2009 PowerPoint presentation by Mitchell Pratt, Clean Energy.

125 California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF

126 Natural Gas Supply Association, News Release, October 8, 2008, "Natural Gas from Shale Could Double in Next Ten Years."

127 Hydraulic Fracturing Fact Sheet, July 2010 Chesapeake Energy

128 As an example, see guidelines developed by New York for the use and disposal of water, the protection of groundwater, and the use of chemicals. Department of Environmental Conservation, New York State, Final Scope for Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program, February 2009.

Upstream Fuel Infrastructure

The most significant aspect in upstream infrastructure for natural gas is the network of interstate and intrastate pipelines. As mentioned, more than 87 percent of California's natural gas supply arrives from a combination of five interstate pipelines, with the remainder delivered strictly within the intrastate pipelines. Given the miniscule amount of natural gas used in California for transportation purposes, increasing the amount of natural gas required within California for transportation purposes is unlikely to have a significant impact on this network.[129] However, the Energy Commission will continue coordinate with other western state agencies on the development of a natural gas transmission and storage system that can overcome any periodic disruptions in supply and reliability.[130]

Aside from supply and reliability issues, there are issues of natural gas purity standards that may impact natural gas for transportation purposes. The ARB is responsible for adopting quality standards for natural gas used in vehicle engines, while the CPUC is responsible for quality standards in the natural gas pipeline. North American pipeline gas generally meets ARB specifications, but roughly eight percent of in-state pipeline gas does not. To address these discrepancies, the ARB is evaluating potential changes to its CNG specifications, including the use of new performance indicators, such as a methane number or Wobbe Index.[131]

Natural gas, when used for transportation purposes, may also require extra treating to remove solids, free liquids, and reduce water vapor content to acceptable levels. Once sufficiently treated, the natural gas is can be compressed into CNG, which compresses pipeline natural gas to less than one percent of its standard volume. CNG is then either used by vehicles on-site, or distributed to local fleet and retail fueling stations via delivery trucks. Alternatively, natural gas can be liquefied into LNG, which has roughly half the volume of CNG. This makes LNG more efficient to distribute over long distances to where pipelines may not exist (often by ship, rail or truck). However, this liquefying process consumes additional energy, which results in higher well-to-wheel GHG emissions from LNG (83.1g CO_2e/MJ) when compared to CNG (68.0g CO_2e/MJ).

Biomethane

Methane derived from renewable resources, also known as biomethane, can be integrated into the upstream natural gas fuel infrastructure supply chain. The most direct application is to inject biomethane directly into the natural gas pipeline. However, there are a number of barriers to this approach. Expensive gas quality testing and interconnection fees, as well as different gas quality requirements between utilities, represent the first significant obstacle. Additionally, existing law effectively restricts biomethane derived from landfill gases to be injected into the natural gas pipeline.[132] Finally, a biomethane producer must be located close to the natural gas pipeline.

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129 Department of Energy, "California Natural Gas Summary," http://www.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_SCA_a.htm

130 California Energy Commission, *2009 Integrated Energy Policy Report*, CEC–100–2009–003-CMF.

131 California Air Resources Board, *Compressed Natural Gas (CNG) Motor Vehicle Fuel Specifications*, May 19, 2010.

132 Assembly Bill 4037 (Hayden) Chapter 932, Statutes of 1988.

Alternatively, biomethane can be combined with gas from the pipeline for direct conversion into CNG or LNG. Biomethane can also be kept separate from natural gas, and used as pure, low-carbon fuel. This is particularly applicable in situations where the supply of biomethane is collocated with the demand for natural gas as a transportation fuel, such as dairy farm vehicles or waste management fleets. For example, the Energy Commission is providing a combination of grant and loan funding for Northstate Rendering to produce biomethane from rendering waste, which will be compressed and supplied to an on-location fueling station, which serves a fleet of local trucks.

The use of biomethane as a low-carbon substitute for transportation natural gas is only one possible use for biomethane. Other opportunities include the use of biomethane for the production of renewable hydrogen, for reducing the lifecycle carbon intensity of other biofuels, or for use in generating renewable electricity (whether for use in the transportation sector or other sectors). All of these applications help reduce GHG emissions and fossil fuel dependence, and would assist the state in meeting a number of its climate and energy policies.

Retail and Fleet Fueling Infrastructure

One of the primary barriers to the penetration of natural gas vehicles is the lack of available fueling infrastructure. Until this problem is addressed, the use of natural gas vehicles will likely be confined to medium- and heavy-duty vehicles, which can use CNG/LNG stations on a regular route.

Fueling infrastructure for natural gas vehicles in California includes a combination of public and/or private access, CNG and/or LNG dispensing, and fast fill or time fill for CNG dispensing.[133] The number of stations is presented in Table 13 below.

Table 13: Natural Gas Fueling Stations

	Publicly Accessible Stations	Private Access Stations
CNG	130 (0 time fill only)	85 (8 time fill only)
LNG	13	19

Source: Department of Energy Alternative Fuels and Advanced Vehicles Data Center

Home refueling options for natural gas also exist, primarily for the light-duty vehicle market. These home refueling stations typically have a long refill time (up to 10 hours). An example of this technology used in the United States is the “PHILL” Fuelmaker which compresses natural gas from a standard utility gas line for use in a CNG vehicle. The new PHILL unit is expected be ready for production and sale in North America within the next several months[134], making home refueling more accessible for natural gas vehicle owners.

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133 Fast fill and time fill refers to the speed at which a natural gas vehicle is refueled. Fast fill dispensers can perform a complete fill within several minutes. Time fill dispensers require several hours, often overnight. However, fast fill dispensers require more expensive equipment and maintenance. Fast fill dispensers are the only practical type of dispensers for public retail fueling stations, which necessarily serve multiple vehicles each day. However, time fill stations are expected to be more economical for dedicated fleet users.

134 Phone conservation with Michael Eaves, Clean Energy on January 6, 2011

Table 14 presents Energy Commission estimates of current natural gas infrastructure costs, based on the station's size (measured in standard cubic feet per minute [scfm] for CNG and gallon capacity for LNG). All of the prices for CNG stations are presumed to include fast fill dispensers, which may not be necessary for certain applications (such as those that return to a designated station overnight). To reduce the impact of these estimated station costs, the federal government offers a tax credit for up to 30 percent of the cost, not to exceed $30,000, if the station is installed in 2011.

Table 14: Natural Gas Infrastructure Costs

Infrastructure Type	Estimated Costs[135]
Small CNG Station (≤ 500 scfm)	$400,000
Medium CNG Station (500-2,000 scfm)	$600,000
Large CNG Station (≥ 2,000 scfm)	$1,700,000
Large LNG Station (≥ 15,000 gallons storage capacity)	$1,700,000
Combined CNG & LNG Station	$2,000,000
Home Fueling	$3,600[136]

Source: California Energy Commission

Self-contained dispensing systems, such as the Galileo Nanobox, also offer the option to provide small fuel dispensers at existing fuel stations. This significantly reduces the cost of new natural gas fueling infrastructure by utilizing existing land, concrete infrastructure, and canopies.

The Energy Commission has invested $5,741,388 for the installation of 20 new stations or upgrades to existing stations across the state; 16 CNG stations, three LNG stations, and one combination station. Some of these stations include multiple dispensers at the same site. Each of these installations was targeted to match the fueling needs of particular fleets and natural gas customers.

Discussions with vehicle manufacturers, fuel providers, local air districts and other program stakeholders revealed that additional investment in natural gas infrastructure is critical to the adoption of natural gas vehicles and market transformation for this alternative fuel.[137] Fuel accessibility is one of the key considerations for fleet managers for the purchase of natural gas vehicles. Increased demand for clean fuel alternatives to gasoline and diesel along with regulatory requirements, such as the South Coast Air Quality Management District Fleet Rule, has driven an increase in natural gas infrastructure by private investors.

The combination of CNG and LNG dispensing at a single station is a particularly attractive option because LNG can be gasified into CNG with conventional pumps using less energy than it takes to compress pipeline gas into CNG. These stations also allow the station owner to serve different markets using much of the same support equipment, such as canopy and pavement,

135 Estimates based on submitted proposals as well as discussions with industry representatives.
136 Consumers Reports, March 2008, Review of the 2008 Honda GX
137 Industry meetings with Freightliner, Kenworth, Navistar, Westport, December 2010 – January 2011

without a significant difference in the cost of the station. These combination stations also support the corridor approach to refueling, making CNG and LNG available along major goods movement corridors to support regional and interstate trucking operations. These corridors typically run through areas with the worst air pollution, making a stronger case for fueling infrastructure to support cleaner vehicle technologies.

As mentioned above, the corridor refueling concept is overwhelmingly support by both industry and government. The Interstate Clean Transportation Corridor (ICTC) project, supported by the Department of Energy, employs public and private partnerships to expand alternative fuel vehicle use and refueling station access throughout the Western United States. The ICTC has successfully developed 23 natural gas refueling stations in California and Nevada[138]. The ICTC continues to work to build a sustainable corridor of LNG refueling stations along the I-15, I-80, and I-5 corridors connecting Southern California, Salt Lake City and Northern California in order to support the movement of goods by alternative fuel heavy-duty trucks throughout the Western United States. Several of the stations proposed for funding by the Energy Commission will directly support corridor refueling along I-10, I-5, CA-99, and other in-state goods movement corridors.

Recent federal funding further demonstrates government and industry support to expand refueling infrastructure along goods movement corridors. On example of many is the Department of Energy's award of nearly $5.6 million for a LNG station in Las Vegas, Nevada that will provide a 700-mile LNG fueling corridor along one of the nation's most heavily traveled truck routes for the movement of various goods.[139]

The aging stations and equipment in California do not meet fleet refueling needs of today. Many fleets involved in goods movement are concerned with the bottom line, which is, in part, dependent on the reliability of fueling equipment and time it takes to refuel their fleets. In the 2010-11 Investment Plan, the Energy Commission dedicated $2 million to natural gas station upgrades. While the Energy Commission has not yet issued a solicitation for this allocation, this funding will likely be substantially oversubscribed based on conversations with managers of existing stations, especially those serving school district bus fleets and growing transit fleets.

Recognizing that market transformation for natural gas will only occur when range anxiety and fleet fueling operations are addressed, the Energy Commission proposes an allocation of $8 million to support the installation of new natural gas fueling infrastructure and upgrades to existing infrastructure. Based the Energy Commission's cost share for the 20 natural gas station projects funded from the infrastructure solicitation, this funding will support approximately 30 new stations and existing station upgrades.

Light-Duty Vehicles

In 2009, there were 36,100 NGVs of all sizes registered in California. Of these, light duty vehicles represent 69 percent of the total NGV population, but consume only 12 percent of the natural

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138 Interstate Clean Transportation Corridor, "About the Interstate Clean Transportation Corridor," http://ictc.gladstein.org/aboutictc.html

139 Department of Energy, "Secretary Chu Announces Nearly $300 Million in Clean Cities Grants to Support Clean Fuels, Vehicles, and Infrastructure Development," http://www.energy.gov/7843.htm

gas fuel used as vehicle fuel. At the present time, Honda is the only original equipment manufacturer (OEM) that offers a light-duty passenger natural gas sedan in the U.S. The Honda Civic GX is comparable to the conventionally fueled Honda Civic DX, but possesses a maximum vehicle range of 225-250 miles on a full tank, with a fuel tank capacity of approximately 8 gasoline gallons equivalent. In 2010, General Motors announced that it would begin offering natural gas versions of cargo van models (Chevrolet Express and GMC Savanna), intended for commercial fleets. Worldwide, however, the market for natural gas vehicles is much wider; General Motors alone, mainly through its Opel subsidiary, offers 18 NGV models for the world market.[140]

In addition to OEM models, some companies offer conversions to natural gas. California regulations prohibit the after-market conversion of emission-controlled vehicles with retrofit systems to operate on an alternative fuel, such as natural gas, unless the converted vehicles and engines have been evaluated and certified by the ARB. Two firms (Baytech and BAF) have ARB certification to convert light-duty conventional vehicles to light-duty dedicated NGVs. Baytech offers various GM light- and medium-duty vehicles on an aftermarket basis (including pickups, vans, and cutaways). BAF offers natural gas Ford Crown Victoria (used for taxis), as well as E-series passenger cargo vans and F-series pickup trucks.[141] Additional firms, such as Natural Drive and Altech-Eco, have obtained emissions certification from the U.S. Environmental Protection Agency for certain dedicated and bi-fuel vehicle conversions, but have not obtained full certification from the ARB.[142] In 2007, California-based IMPCO sold approximately 13,000 natural gas and propane conversion kits per month to the world market, but none in California, primarily because of the expense required to comply with current ARB certification.[143]

Upfront vehicle costs remain a significant issue for the light-duty NGV market. The incremental cost for OEMs' NGV offerings ranges from roughly $9,600 for the Civic GX to $15,910 for the Chevrolet Express and GMC Savana. These incremental costs are roughly in-line with the cost of converting a conventional pick-up truck to natural gas, approximately $15,500.[144] A federal tax credit for the purchase of light-duty OEM NGVs and for the conversion of light-duty vehicles to natural gas expired at the end of 2010, leaving customers with a high upfront vehicle cost. When natural gas prices are lower than gasoline, owners of these vehicles can expect to recoup some of this initial cost difference. The federal fuel excise tax credit, currently extended through 2011, offers consumers an additional $.50 per gasoline gallon equivalent.[145] Additionally, most natural gas vehicles are permitted single-occupant access into California's high occupancy vehicle lanes, which makes them a more attractive proposition.

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140 Letter dated January 23, 2009 to California Energy Commission, Docket # 08-ALT-1 AB 118 Advisory Committee, by Pete Price of The California Natural Gas Vehicle Coalition (CNGVC).

141 NGV America, "Guide to Available Natural Gas Vehicles and Engines," http://www.ngvamerica.org/pdfs/marketplace/MP.Analyses.NGVs-a.pdf

142 NGV Global News, January 29 2010, confirmed by Seong Kim of CARB

143 Presentation by Tim Standke, IMPCO at the "Natural Gas and Propane Workshop" on September 18, 2009.

144 Email from Matt Weiss, NGV America, dated December 14, 2010. Email from Tom Sheehan, NGV America, dated December 14, 2010.

145 U.S. Department of Energy, "Federal Incentives and Laws for Natural Gas," http://www.afdc.energy.gov/afdc/laws/laws/US/tech/3253

Given anticipated changes to the ARB's Low Emission Vehicle (LEV) regulations, the regulatory environment for CNG vehicles in California is favorable. The ARB is proposing to revise current LEV regulations to achieve Super Ultra LEV exhaust emissions fleet average by 2022 (LEV III). More importantly for NGVs, CARB is proposing to lower current evaporative emissions standards and effectively require that larger proportions of California vehicles must be certified for zero evaporative emissions. CNG vehicles will be relatively easy to certify to exhaust emissions below SULEV and the zero evaporative standards.

Table 15: Natural Gas Funding Allocation

Natural Gas Fueling Infrastructure	$8 Million
Medium- and Heavy-Duty Vehicles Deployment Incentives	*See Medium- and Heavy-Duty Vehicles section*
Total	$8 Million

Source: California Energy Commission

Propane

Propane can offer significant and immediate petroleum use reductions and moderate GHG emission reductions. Currently, propane can be produced as a byproduct of either natural gas processing or petroleum refining; however, current research is showing promise in the production of propane from renewable resources. According to the WPGA, California consumed approximately 620 million gallons of odorized propane in 2008, and 70-80 million gallons of this consumption was used specifically for on- and off-road vehicles.

Propane is very attractive in terms of pricing compared to both diesel and petroleum, and if federal excise tax credits for propane use continue to be made available in the future, propane will be a viable option for fleets. According to the federal Department of Energy, the average cost for propane is $2.69 per gallon.[146] The federal government also offers a fuel use tax credit of $0.50 per gallon-gallon equivalent, which acts as an incentive to propane users to offset the energy loss with the use of propane in vehicles. Propane's energy content is approximately 25 percent less than gasoline. Even with the energy loss, propane's price remains attractive to fleets as an alternative fuel option.

Upstream Fuel Infrastructure

From the refinery or processing plant, propane is shipped in two stages—first, to an intermediate terminal and from there to the local propane supplier for delivery to the end user. All propane is transported under pressure in its more compact liquid form. Propane is mainly transported via a pipeline and truck combination, but can also be transported via rail in steel cylinders. Propane being transported to California from Texas is primarily transported via pipelines.

Two types of trucks are used for propane transportation: a highway transport (which typically carries 7,000 to 12,000 gallons) and a smaller bulk delivery truck, called a "bobtail" (which carries 1,000 to 5,000+ gallons). Both types of trucks are constructed of high-strength steel.[147]

Approximately 60 percent of propane used in California is produced in California refineries, while the rest of the propane imported typically comes from Texas, the Midwest, and Canada. While a majority of the propane used in California is domestically produced, this number can vary depending on seasons. California tends to be a net exporter in the summer, while the amount of propane it imports in the winter can increase significantly if California has an especially cold winter.

Local Fuel Infrastructure

Propane retail infrastructure is already widely available and can easily be expanded as demand for propane as a transportation fuel increases. There are approximately 228 propane fueling stations already in place for vehicles in California according to the Department of Energy's Alternative Fuel and Advanced Vehicle Data Center. California has the second largest number of accessible propane fueling stations for vehicles in the nation, which can already support an

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146 As of July 2009, according to U.S. DOE ERRE Price report. Does not include excise tax credit.

147 National Propane Gas Association Propane, "Facts About Propane," http://www.npga.org/files/public/Facts_About_Propane.pdf

expanded vehicle market with funding for light- and medium-duty vehicles.[148] Infrastructure for propane vehicle fueling could expand quickly, as existing propane dispensing stations can be used for vehicle fueling through the addition of fuel capacity, a tank pump, and metering equipment. With the addition of this equipment, virtually any propane tank/ station in California can be retrofitted to meet a propane vehicle's needs. Additionally, many fuel suppliers have indicated that they are willing to enter into a contract to install fueling equipment and stations for propane fleets at no charge, given the fleet has a minimum monthly throughput. This will facilitate the increasing demand for propane as a transportation fuel in the years ahead.

Due to its low cost and ease of installation, a minimal amount of funding is needed to support propane infrastructure. Based on information contained in applications for the DOE's Clean Cities program, coupled with propane working group information, the Energy Commission estimates that the cost of a fueling station is $35,000 to $50,000 for a 2,000 gallon storage tank, and $75,000 to $150,000 for a 30,000 gallon tank, including 4 dispensers. Additionally, federal incentives already offer a sufficient amount of support for propane infrastructure, as indicated in Table 16.

Table 16: Propane Infrastructure Summary

Current Stations in California	228
Station Costs	2,000 gallon storage tank: $35,000-$50,000 30,000 gallon storage tank: $75,000-$150,000 Station equipment upgrades: $2,000
Federal Incentives	Up to 50 percent or $50,000 of infrastructure installation costs for stations installed after January 1, 2009

Source: California Energy Commission

The Energy Commission intends to provide support for Northern California sector pilot project for regional use of propane autogas. This funding would cover the cost of approximately 10 stations along the I-5 corridor in Northern California. This funding supports a larger effort to launch a pilot project in the Northern California region, which integrates vehicle deployment, infrastructure development, and workforce development for the alternative fuel industry. Propane is considered the most viable option for alternative fuel market development in Northern California, where propane is easily accessible. This pilot project will also serve as a model for the impact and benefits propane as autogas can have in rural communities with limited access to other alternative fuels. For this purpose, the Energy Commission allocates $500,000 for propane fueling infrastructure.

Light-Duty Vehicles

Currently, the Roush F-150 is the only light-duty propane vehicle certified by the U.S. EPA and ARB. Additionally, Roush will be seeking certification in the coming months for a propane F-

148 Department of Energy, "Alternative Fueling Station Total Counts by State and Fuel Type," http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

250 truck, and E-150, and 250 cutaway vans, which have attracted interest from several fleet owners already.[149]

The incremental cost for purchasing a light-duty propane vehicle ranges from $7,500 to $10,400. Roush anticipates that a $3,500 per vehicle incentive is needed to generate sales and stimulate the growth of the light-duty propane market.[150] Nonetheless, fleet owners have expressed interest in using propane as an alternative to gasoline because of its cost and availability.

With the emergence of new propane vehicles in 2010 and 2011, there is an increased interest in using light-duty vehicles as part of delivery, airport, and utility fleets. Given the new models, current propane fuel pricing, and reasonable buy-down costs for these vehicles, funding availability for these vehicles will help ensure the purchase of an alternative fueled vehicle over a gasoline or diesel vehicle.

Other states across the nation already widely use propane in their public fleets. Recently Texas was awarded $25.5 million for propane vehicle and infrastructure development. Of the 882 vehicles being deployed, 645 of these vehicles will be light-duty vehicles for use by public school and business fleets. Market readiness for these vehicles will allow them to serve as an early action in reducing GHG emissions in the transportation sector.

Manufacturers indicate that providing funding support in the form of vehicle incentives in the first few years is critical to the growth of the propane vehicle market in California. Propane can play an especially significant role in rural communities, who may not have the option of using other alternative fuel vehicles due to the lack of infrastructure. Propane is readily available in most rural communities in California already, and the cost of installing either an entire station or the appropriate fueling equipment for autogas use is very affordable. As the market grows in California, manufacturers anticipate that the need for funding support will decrease by approximately 20 percent each year.

Roush estimates that covering about 30-35 percent of the incremental vehicles cost is sufficient to stimulate propane vehicle sales. Considering the funding available for propane vehicles through the Energy Commission's anticipated gaseous fuel incentive program for $3 million in 2011, along with incentives for vehicles being offered through the WPGS through August 2011, it is anticipated that these funds will be sufficient to cover expected vehicles through 2011. For expected vehicles sales through June 2012, the Energy Commission intends to allocate $1,000,000 to support the growth of the light-duty propane vehicle market in California.

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149 Todd Mouw, Roush, Meeting, January 5, 2011.

150 Todd Mouw, Roush, e-mail, September 8, 2009.

Table 17: Propane Funding Allocation

Fueling Infrastructure	$500,000
Light-Duty Vehicle Incentives	$1,000,00
Medium- and Heavy-Duty Vehicle Incentives	*See the Medium- and Heavy-Duty Vehicle Section*
Total	$1,500,00

Biofuels

Feedstocks

There is a broad variety in the feedstocks available for alternative and renewable fuels. For the purpose of the Investment Plan, these feedstocks are divided into three categories: waste-based, purpose-grown, and conventional. For each feedstock, common characteristics are addressed, such as volume, sustainability, carbon intensity, market potential, and likely fuel pathway. By identifying and contrasting these characteristics, the Energy Commission can weigh the relative advantages and disadvantages of each feedstock.

Most biofuels used in California continue to be derived from purpose grown feedstocks such as corn and soy. Internationally, oil palm and sugar cane predominate as biofuel feedstocks. All four of these major feedstocks can be grown economically at industrial scales, yet all create serious sustainability concerns. The Energy Commission is seeking to identify and promote alternative biomass-based feedstocks that can serve as the basis for liquid and gaseous fuels for California's transportation sector. Most waste-based and alternative feedstocks face substantial challenges and barriers to market entry; high costs, uncertain supplies, and not yet commercially viable process technologies prevent waste-based feedstocks and alternative feedstocks from forming a larger basis in California's alternative fuels markets. This year's Investment Plan investigates waste-based and alternative feedstocks in more detail than in previous years in order to better understand their potential and market barriers and identify specific opportunities to advance their development through the ARFVT funding. This enhanced investigation also complements Energy Commission work to review and update the Bio Energy Action Plan.

Waste-Based Feedstocks

This category includes feedstocks which can be used as a source of transportation fuel but would otherwise need to be landfilled or disposed of in some other way. California's robust agricultural and food processing sectors generate large volumes of biomass-based waste material that is potentially suitable for low carbon alternative fuel production. Landfills, urban transfer stations and wastewater treatment plants also generate high volumes of waste materials with similar potential. These waste-based feedstocks avoid difficult issues, such as the use of high productivity arable lands for fuel production, sustainability or indirect land use effects. These feedstocks also foster some of the highest GHG emission reductions. For these reasons, the Energy Commission is particularly interested in expanding the use of waste-based feedstocks, such as those identified below, in the creation of alternative and renewable transportation fuel. The volume and fuel potential for these feedstocks are summarized in Table 18.

Table 18: Waste-Based Feedstock Volumes and Fuel Potential

Feedstock	Volume Technically Available[151]	Biomethane Potential (BCF)	Biofuel Potential[152] (million gge)	DGE Potential (million)
Agricultural Residue	4.3 MBDT	9.3[153]	302	261
Animal Manure	3.8 MBDT	14.6	127	110[154]
FOG	14.4 M lbs	Unknown	63.6	55
Food Wastes	0.8 MBDT	1.9[155]	56	48
Forest Biomass Waste (via cellulosic ethanol)	14.2 MBDT	N/A	784[156]	678
Forest Biomass Waste (via gasification)	14.2 MBDT	30.7[157]	1000	864
Landfill Gas	79 BCF	39.5[158]	368	318
Municipal Solid Waste	10 MBDT	25.9[159]	704	608
Waste Water Treatment Plants	9.6 BCF	4.8[155]	45	39
Total		126	2,566[160]	1,755[158]

Agricultural Residue

A large source of available biomass in California will come from agricultural residues. Agricultural residues can be processed using a variety of technologies, producing process heat, electricity, and/or transportation fuel as an end product. When looking at the transportation sector, agricultural residues are often processed using technologies including, but not limited to, gasification, anaerobic digestion, fermentation and hydrolysis to produce either liquid or gaseous transportation fuels such as hydrogen, biogas, and cellulosic ethanol.

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151 Technical potential accounts for residues needed to maintain soil fertility and tilth or for erosion control purposes. There are a number of technical and social constraints that can limit the amount of biomass that can be sustainably collected.

152 California Biomass Collaborative, "California Biomass and Biofuels Production Potential" December 2007. Assumes thermochemical process of gasification followed by Fischer-Tropsch synthesis. Does not assume any constraint for moisture content. 27 million BDT yields 1.9 billion gge, unless otherwise noted.

153 Ken Krich, "Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California" July 2005. Assumes 2.4 MBDT of agricultural residues yields 5.2 BCF of methane.

154 California Biomass Collaborative, 2008

155 Ken Krich, "Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California" July 2005. Includes meat processing waste, cheese whey, and food processing waste.

156 Brian Hunt, "Woodwaste to Ethanol: A Second-Generation of Ethanol Process" Presented at Ethanol Policy Forum, October 24, 2008. Current technology has proven 1 BDT of wood waste to yield 45 gallons of ethanol but believe yield of 80 gallons of ethanol possible.

157 Assumes same conversion ratio used for agricultural residues

158 Assuming 50 percent methane content

159 Ken Krich, "Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California" July 2005. Includes landfilled manure, landfilled composite organic waste, landfilled food waste, landfilled green waste.

160 Assumes forest biomass converted using gasification process.

Primarily comprised of orchard and vine, field and seed, and vegetable residues, agricultural residues will most likely be sourced from the Central Valley as well as the coastal and southern valleys.[161] With California having 9.15 million acres of crops planted in 2007, there is a gross potential of 8.7 MBDT per year and a technical potential of 4.3 MBDT per year of agricultural residues available for conversion to energy.[162] Based on the technical potential, this is enough to produce 220 million gasoline gallon equivalents annually through 2020.[163]The GHG reduction when using agricultural wastes as a feedstock can vary significantly depending on the feedstock characteristics, conversion technology, and fuel produced, however, reductions can potentially be significant – around 80 percent for cellulosic technologies and in the mid 80s for some anaerobic digestion processes.[164] Also, because agricultural residues are classified as a waste stream, they could be considered highly sustainable when collected and processed in a sustainable manner.

The Energy Commission proposed nearly $1.5 million in funding for the Advanced Bioenergy Center Mendota. This project integrates four different technologies in one facility to produce advanced ethanol, renewable biomethane, compost and fertilizer, and green e-electricity, using sugar beets and almond prunings as feedstocks. Once this project is complete, it will convert an estimated 80,000 tons of almond prunings to produce 6.3 Megawatts of certified green-e electricity.

Some of the most difficult components to navigate when considering using agricultural residues as a feedstock are collection, transport and storage. Collecting and transporting waste residues can be costly and could potentially jeopardize the economic feasibility of a project. A key to reducing transport costs is to locate production facilities within close proximity of feedstock sources when possible, preferably within 50 to 100 miles.[165] Although transporting feedstock using rail or barge are options, often these residues are transported by truck as it allows for the greatest amount of flexibility. The cost of transporting via truck can range from $0.12 to $0.23 per ton-mile and is heavily dependent on the price of diesel.[166] Another factor to consider is the seasonality of agricultural production. Crops are seasonal in nature and production facilities will have to adjust to feedstock supplies through either a variety of crop residues or expanded storage capabilities.[167]

Animal Manure

Animal manure is an optimal feedstock for producing energy or biofuels because it is a waste stream available in California. California's agricultural animal population is close to 70 million,

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161 California Biomass Collaborative "Biomass Resource Assessment for California", 2007.
162 California Biomass Collaborative "Biomass Resource Assessment for California", 2007. Technical potential accounts for residues needed to maintain soil fertility and tilth or for erosion control purposes. There are a number of technical and social constraints that can limit the amount of biomass that can be sustainably used.
163 Draft Bioenergy Action Plan, 2010. Number found in Bioenergy Action Plan reduced to exclude animal manure and food processing.
164 GHG Reductions based on staff estimates.
165 Draft Bioenergy Action Plan, 2010.
166 Draft Bioenergy Action Plan, 2010.
167 California Biomass Collaborative "Biomass Resource Assessment for California", 2007

the majority being poultry and cattle.[168] The manure these animals generate has a gross potential of over 11 million BDT per year and a technical potential of 3.8 million BDT per year.[169] Anaerobic digestion of animal manure creates biogas, which has a potential of 14.6 BCF or 110 million DGE.[170] The biogas can be cleaned and used as biomethane, or burned to generate heat or electricity.

If the manure is kept on the farm, it can be collected by flushing the barn with water or by scraping. Once collected, the feedstock is anaerobically digested onsite, or special transport companies collect the manure and take it to centralized anaerobic digesters. The quantity of biogas produced depends on how the manure is collected and stored. Generally, the fresher the manure, the greater the biogas generation potential.[171] Manure has an estimated 80 percent to 85 percent GHG emission reduction from the diesel baseline.

A number of dairies in California use manure as a feedstock for producing energy; however, most of those facilities are producing electricity. Only the Hilarides Dairy, located in Lindsay, California, is producing a transportation fuel. The Hilarides Dairy originally collected biogas for electricity generation, but has since expanded to producing biomethane that is used onsite in milk trucks. This is a small scale demonstration project; currently, no commercial projects are using animal manure to produce transportation fuel in California.

One of the greatest challenges of using manure as a feedstock is the limited number of large dairies and farms. Scale of production is an important factor in determining economic feasibility. An alternative to large dairies or farms are clusters of smaller ones that could transport their feedstock to a central anaerobic digestion site. Another challenge is access to an end use market. Once biomethane is produced, it needs to be distributed to the transportation market or used onsite in agricultural vehicles such as tractors, combines, threshers, pickup trucks, and milk trucks. If the volume produced exceeded what could be used onsite, the excess would have to be either trucked or piped to a location where it could be sold into the market.

Fats, Oils and Greases

When waste fat, oil, and grease (FOG) from restaurants is dumped down drains, it solidifies and clogs sewers. To prevent clogs, some wastewater service areas require restaurants to collect FOG in grease traps. The FOG can then be picked up, delivered to a wastewater treatment facility, and converted to biodiesel or added to anaerobic digesters to produce gas for electricity.

Before conversion to biodiesel, brown grease needs to be separated from FOG by screening, settling, heating, and filtering. Wastewater high in organics is left over; water is recovered from it, and the remaining material can be added to an anaerobic digester. The brown grease is then converted to biodiesel. Because it is high in free fatty acids, it requires an acid catalyzed process

168 California Biomass Collaborative, "An Assessment of Biomass Resources in California" December 2006

169 Ibid

170 California Biomass Collaborative, 2008.

171 Ibid

before transesterification—the traditional process used to produce biodiesel. Glycerin, methanol, and water are the remaining co-products.[172]

Research studies suggest that the best use of FOG is conversion to biodiesel. In one study, the net energy comparison showed 1120 kilojoules per liter-FOG for biodiesel and 1010 for anaerobic digestion, and the greenhouse gas comparison showed a reduction of 0.48 kilograms carbon dioxide per liter-FOG for biodiesel and 0.23 for anaerobic digestion.[173] Challenges to using FOG for biodiesel production include foul odor, content of up to 98 percent free fatty acids, contamination with food and trash, need to remove sulfur, heavy emulsification, cold flow (FOG is solid at room temperature), and water contamination.

The gross amount of available FOG was calculated for the U.S. by Wiltsee.[174] Using Wiltsee's results for Sacramento, about 414 million pounds of FOG are available per year in California (11.2 pounds per person * 36,961,664 people[175]). Because it takes about 7.5 pounds of FOG to make one gallon of biodiesel, potential production of biodiesel is about 55 million gallons per year. According to a 2011 report from RAND Corporation, fuels derived from animal fats and waste oils will never have a significant role in the larger domestic commercial marketplace because of limited production potential.[176]

Despite an upward cap on market growth, producing fuel from FOG in wastewater service areas with a large quantity of readily available feedstock will stop 75 percent of sanitary sewer overflows, keep FOG out of landfills, help meet California's Bioenergy Action Plan goals, reduce reliance on fossil fuels, and reduce greenhouse gas emissions.[177] FOG-based biofuel has the potential to make a modest contribution to meeting California's goals for low carbon biofuel use. Current fuel production demonstrations and conversion technology research efforts include:

- East Bay Municipal Utility District (EBMUD) is using Program funds to build a FOG receiving station and small-scale biodiesel production facility.
- San Francisco Public Utility Commission (SFPUC) is using Energy Commission-PEIR funds to test removal of brown grease from FOG and produce biodiesel. SFPUC is using licensed technology from BlackGold Biofuels.

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172 URS Corporation, "FOG Control & Beneficial Reuse: A Case Study in San Francisco," http://www.pprc.org/BrownGreaseSymposium/docs/Presentations/URS_Presentation_15APR09.pdf
173 Chakrabarti, Alicia R., John M. Hake, Idit Zarchi, Donald M.D. Gray. 2008. Waste Grease Biodiesel Production at a Wastewater Treatment Plant. Water Environment Federation.
174 Wiltsee, G., Appel Consultants, Inc., Urban Waste Grease Resource Assessment, November 1998 NREL/SR-570-26141.
175 U.S. Census Bureau, "California QuickFacts," http://quickfacts.census.gov/qfd/states/06000.html
176 Bartis, James T. and Lawrence Van Bibber (RAND Corporation), 2011, Alternative Fuels for Military Applications, http://www.rand.org/pubs/monographs/MG969.html.
177 San Francisco Public Utilities Commission, "San Francisco's Future Bioenergy Park Phase I: FOG-to-Biodiesel," http://www.energy.ca.gov/proceedings/2008-ALT-1/documents/2009-02-11_workshop/presentations/Lewis_Harrison.PDF

- BlackGold Biofuels, a Pennsylvania-based company, has developed technology to produce high quality biodiesel from FOG.
- BioFuelBox mini-refinery, a San Jose-based company, developed a process to separate wastewater into proteins and carbohydrates for anaerobic digestion, and lipids for biodiesel.[178]
- Piedmont Biofuels, a North Carolina-based company, opened a plant in 2010 to produce biodiesel from waste grease.[179]

Restaurants pay third-party companies to clean out grease traps and dispose of FOG. For wastewater treatment districts such as EBMUD and SFPUC, the third-party companies deliver FOG to the district's receiving station, where they pay a tipping fee. EBMUD's receiving station, which will be built with Program funds, will have truck unloading bays, below-grade concrete tanks to receive the FOG, screens to remove large solids, grinders, pumps, blend tanks, and an odor treatment system. EBMUD's FOG receiving station is expected to cost $1.5 million. The small-scale equipment used to separate brown grease from FOG is expected to cost about $350,000.

Food Waste

Food waste includes waste products from fruits and vegetables processed by canners, freezers, dryers, and dehydrators, as well as nut shells, fruit pits, rice hulls, cotton gin trash, and whey resulting from producing cheese. The League of California Food Processors estimates that 14 tons to 16 tons of fruits and vegetables are processed every year in California.[180] The gross food waste potential is 1 million BDT per year, and the technical food waste potential is 0.8 million BDT per year.[181] However, when using food waste as a feedstock, one of the biggest challenges is seasonal availability.

Food waste would most likely be anaerobically digested to produce biomethane, but it can also be fermented to produce a gasoline alternative. Parallel Products, a company that runs a number of recycling facilities nationwide, uses beverage waste to produce ethanol at their Ontario, California facility. Through the fermentation of sugar laden liquids and the distillation of alcohol from beverage and industrial waste streams, Parallel Products produces over five million gallons of waste-derived ethanol annually.[182]

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178 Treatment Plant Operator, "Mini-Refinery Converts Fats, Oils and Grease into Biodiesel," http://www.tpomag.com/editorial/view/2161/Mini-Refinery-Converts-Fats-Oils-and-Grease-into-Biodiesel

179 Herald Sun, "Biofuel plant to turn waste grease into top-quality fuel," http://www.heraldsun.com/view/full_story/8794804/article-Biofuel-plant-to-turn-waste-grease-into-top-quality-fuel

180 Ken Krich, Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California, July 2005

181 California Biomass Collaborative, "Biomass Resource Assessment for California, Draft Report" April 2005

182 Parallel Products, "Ethanol Recovery and Production," http://www.parallelproducts.com/ethanol.html

The best "use" of food waste is to reduce the amount of waste. The United States Environmental Protection Agency (US EPA) has developed a food waste recovery hierarchy that recommends food waste be reduced first, then used to feed hungry people, feed animals, or processed for fuel.[183] Assuming that US EPA's campaign is successful, the market potential for fuel made from food waste will be decreasing.

Forest Residue

California's 40 million acres of forestlands face increasing risks from severe wildland fires, due to unhealthy accumulation of forest growth due to historic fire suppression policies and climate change. State and Federal forest agencies recommend active thinning to reduce the risk of high severity fires, potentially creating large volumes of woody biomass waste materials. This situation presents an opportunity to reduce these unstable fuels by using woody biomass from forest restoration as carbon-neutral feedstocks for biofuels. Preliminary estimates indicate that approximately 40 percent of California's total biomass resources are contained within the 40 million acres of forest lands in California.

Estimates of potential forest biomass waste streams available for energy production depend on assumptions and methodology. A recent study by the California Department of Forestry and Fire Protection (CDFFP), funded by the Energy Commission, estimated that gross non-merchantable standing forest and shrub biomass is 1.32 billion Bone Dry Tons (BDT). The proportion of this total that is technically available (not limited by legal or engineering constraints) is 699 million BDT. This study also estimated that potential annual biomass that is technically available from forest management activities would total 14.2 million BDT/year. Assuming a conversion factor of 80 gallons per BDT, this annual volume equates to almost 1 billion gallons per year of ethanol, which would offset about 660 million gallons/year of gasoline. A new cold pyrolosis conversion technology being evaluated by the G4 company through a $1.2 million Program grant in Placer County may produce higher yields of 100+ gge per BDT, and produce a transportation grade biogas. More investment is needed to continue the development and evaluation of technologies with the potential to convert woody biomass waste streams to low carbon transportation fuels.

Cellulosic ethanol production from conifer waste streams is not yet commercially viable due to the technical challenges associated with breaking down the lignens and tannins found in conifer softwoods. Transport costs can also be prohibitively high when material must be trucked from remote forest locations to potential processing sites. To date, woody biomass feedstocks are used to generate electricity. California has 26 active power plants that consume about 3.2 million BDT annually.

Numerous environmental organizations have raised concerns about sustainability in harvest and use of forest biomass as an energy source. The Energy Commission addressed these issues during the 2008 AB 118 Rulemaking proceeding, and adopted the following sustainability language into its regulations:

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183 U.S. EPA, "Generators of Food Waste," http://www.epa.gov/wastes/conserve/materials/organics/food/fd-gener.htm

> Section 3101.5(b)(2)(F) Projects that use forest biomass resources as part of their feedstock, and that demonstrate the advancement of natural resource protection goals, are those that use forest biomass collection or harvesting practices that do not diminish the ecological values of forest stands, and that are consistent with forest restoration, fire risk management and ecosystem management goals.

The Energy Commission has worked actively with CalFire, the US Forest Service and Air Resources Board through the Interagency Working Group to further define and establish sustainability standards for forest management and thinning. The Energy Commission is using sustainability funding to enter into a $1.5 million research agreement with the US Forest Service and UC Davis to conduct applied research on forest management, thinning, fire risk reduction and other issues associated with forest management and sustainable energy production. The Air Resources Board's LCFS program is also investigating appropriate sustainability standards for woody biomass-based fuels seeking eligibility in the LCFS credit program.

Landfill Gas

Landfill gas (LFG) is methane-rich biogas naturally created as microbes chemically break down the waste in landfills through a complex series of reactions. Landfill gas is generally composed of 40 percent to 60 percent methane, carbon dioxide, and small amounts of other chemicals, such as volatile organic compounds and sulfur-containing compounds.

Due to stringent air quality regulations, LFG may not be released into the atmosphere. The LFG must be captured, and—due to difficulties obtaining air permits in some California air districts—combusted on site or flared. An alternative to flaring LFG is to build LFG-to-energy projects. Once captured, LFG can be cleaned and used as biomethane for transportation fuel, or used to generate electricity.

LFG has a gross potential of 118 BCF per year and a technical potential of 79 BCF per year or about 600 million DGE.[184] For every one million tons of municipal solid waste (MSW) landfilled, 432,000 cubic feet per day of LFG is created.[185] The US EPA has identified 37 candidate landfills in California that could accommodate LFG-to-energy projects.[186]

LFG is a sustainable feedstock because it is derived from waste. On a well-to-wheels basis, it reduces GHGs by 82 percent to 87 percent from the diesel baseline.[187]

Two LFG-to-energy projects in California are producing biomethane for use in the transportation sector. The Altamont Pass Landfill, located in Livermore, California, is the larger of the two, with a capacity to produce 13,000 gallons of LNG per day, fueling 300 local refuse trucks. The second project, located at the Frank R. Bowerman landfill in Orange County, has a

184 Waste Management, "Opportunities for Landfill Gas to Energy and Fuel in California," http://www.biomethanesummit.com/pdfs/presentations/105_SOLID_WASTE_LANDFILL/ChuckWhite.pdf

185 Ted Barnes, CPR Meeting – Task 2.0 Altamont Landfill Gas Purification, Testing and Monitoring Agreement #500-09-004 Presentation, August 31, 2010

186 California Biomass Collaborative, "Biomass Resource Assessment for California, Draft Report" April 2005. http://www.epa.gov/lmop/projects-candidates/index.html#map-area

187 California Air Resources Board Low Carbon Fuel Standard fuel pathway documents.

production capacity of 4,000 gallons of LNG per day and also uses the biomethane produced to fuel refuse trucks.[188] Waste Management Inc. is developing a third landfill gas to energy project using $11 million in AB118 Program funds at the Simi Valley landfill in Ventura County. This high volume project will produce 750 million cubic feet of biomethane annually, equivalent to 6 million gallons of LNG, or 3.4 million dge. Waste Management will use the LNG biogas to power 500 heavy duty refuse hauling trucks.[189]

One of the greatest challenges faced by LFG-to-energy projects is lack of accessibility to the natural gas pipeline. Pipeline injection of biomethane from landfills is currently prohibited even if the gas is treated to meet health and safety standards.[190] Without access to the natural gas pipeline, LFG-to-energy producers need to find alternative methods for moving their product into the market. Some landfills are using the LFG for onsite electricity generation, and others such as the Altamont and Bowerman Landfills are fueling local refuse trucks, but large quantities of biomethane—estimated as high as 50 percent of the total methane captured at California landfills—continue to be flared.[191] Creating uniform gas quality standards between utilities would help bring LFG-to-energy projects to fruition.

Municipal Solid Waste

Municipal solid waste (MSW) is the waste collected, both urban and commercial, before it enters a landfill. The waste stream is composed of 57 percent biomass, which can be separated using various methods, with the remainder being plastics, textiles, and non-organics.[192] Once separated, recycling and composting employ most of the resource but a substantial fraction remains that could be used for energy conversion purposes.[193] The primary use of post-recycled MSW is feedstock for biogas, but it has also been considered as a feedstock for producing ethanol and synthetic diesel.

MSW could be a significant source of feedstock—it has a gross potential of 38 million BDT per year and a technical potential of 10 million BDT per year. The biogas potential is 79 BCF or about 600 million DGE.[194]

Using MSW as a feedstock for producing energy can significantly reduce the waste stream in California's landfills, thus extending the life of landfills. Currently, no Low Carbon Fuel Standard pathway exists for the conversion of MSW to biomethane, but a GHG reduction of up to 75 percent from the diesel baseline is possible, depending on the energy consumption of any necessary pre-treatment processes.[195] California projects should be encouraged to use MSW as a

188 Private Communication with Jesus Perez of Orange County Waste & Recycling, December 9, 2010
189 High Mountain Fuels received funding under PON-09-003
190 Chuck White, Waste Management. June 3 Stakeholder Workshop transcript
191 Ibid.
192 Rob Williams, "Biofuels from Municipal Wastes Background Discussion Paper" March 28, 2007
193 Ibid.
194 California Biomass Collaborative
195 Energy Commission staff.

feedstock because it has ten times greater energy production potential on a per ton basis than landfilled waste.[196]

Currently, East Bay Municipal Utility District is the only facility anaerobically digesting MSW. CalRecycle staff strongly supports the use of MSW as a transportation fuel or energy source. However, a number of project developers are proposing facilities that will use post-recycled MSW as a feedstock. The Energy Commission will provide $4.5 million in ARFVT program funding to CR&R, which operates the Perris Transfer Station in Riverside County. CR&R will construct a 50,000 ton facility that will separate MSW from Los Angeles County. The CR&R project will sort the MSW, anaerobically digest the organic material to produce biomethane, clean it to pipeline standards, and produce a transportation grade RNG that will be used to fuel 60 to 80 vehicles in CR&R's heavy duty truck fleet. Total output will be 120,000 MMBTUS, or 865,000 dge.

As a feedstock, the cost of obtaining MSW would be low or negative because it would otherwise be land filled. It would be easily accessible because it is already collected. Unlike large landfill projects, MSW projects should be smaller and decentralized to reduce the need to transport feedstock over large distances.[197] MSW projects could also be co-located with existing facilities such as recycling centers to minimize storage and transport issues. One of the biggest challenges to using MSW for producing biofuel is the perception that these processes will infringe on recycling and composting efforts. In fact, biofuels projects funded through the AB118 program, such as CR&R, will utilize only post-recycled MSW as a feedstock.

Waste Water Treatment Plants

Waste from wastewater treatment plants (WWTP) generally includes municipal waste water, sewage, and biosolids. WWTPs often deploy anaerobic digesters to stabilize a portion of the waste and also to produce biogas.[198] The biogas can be used to generate electricity or produce biomethane. Waste from WWTPs has a gross potential of 16 BCF per year and a technical potential of 9.6 BCF per year.[199] Biogas potential is about 40 million DGE.

Using waste as a feedstock for producing energy can significantly reduce the waste stream in California's landfills, thus extending the life of landfills. California has more than 240 wastewater treatment plants that treat sewage and other waste prior to discharge. A number of them already have anaerobic digesters installed onsite and are using the biogas produced to generate electricity.[200]

In November, 2009, the Energy Commission awarded a $1 million grant to UC Riverside's College of Engineering-Center for Environmental Research and Technology (CE-CERT) to build a process demonstration unit to convert biosolids to clean synthetic diesel fuel. The unit uses a

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196 1 ton of organic waste landfilled has a 65kW potential while 1 ton of MSW has a 550 kW potential, CEC Meeting with CalRecycle, October 28, 2010

197 CalRecycle, verbal communication, October 28, 2010

198 Rob Williams, "Biofuels from Municipal Wastes Background Discussion Paper" March 28, 2007

199 California Biomass Collaborative, "Biomass Resource Assessment for California, Draft Report" April 2005

200 Ibid

steam hydrogasification process to convert biosolids from the City of Riverside's wastewater treatment facility comingled with green waste.[201]

Yellow Grease

The Energy Commission is further investigating this feedstock.

Purpose-Grown Feedstocks

This section reviews a series of purpose-grown feedstocks used for ethanol and biodiesel production. Some, like algae and switchgrass, have high volumetric potential for renewable diesel or cellulosic ethanol, but face ongoing cost and technology challenges. Others, like corn, soy, oil palm and sugar cane, can be grown efficiently at industrial scales, but engender strong sustainability concerns. For example, recent work by Holly Gibbs of Stanford indicates that global agricultural land acreage increased by 629 million hectares between 1980 and 2000; 100 million hectares of this new agricultural land was created in tropical zones and 55 percent of the tropical zone agricultural land came from newly cleared tropical forests. Palm oil, soy oil and sugarcane account for much of this new agricultural production.[202]

Algae

Algae are organisms that grow in water. They include microalgae and cyanobacteria (both microscopic), and macroalgae (seaweed). They can be grown and processed to produce biodiesel, renewable diesel, biomethane, ethanol, and other fuels. Different types of algae are grown depending on the type of fuel to be produced. Algae can be grown with light in open, mixed or unmixed ponds, or in enclosed plastic bags or tubes (photobioreactors). They can also be grown without light and fed a carbon source, such as sugars, to generate new biomass (heterotrophic cultivation). [203]

The best locations for growing algae are in the southwest and Florida, near fossil fuel plants with waste carbon dioxide. The number of annual average cumulative sun hours should be at least 2800, the annual average daily temperature should be at least 55°F, and the number of annual average freeze-free days should be at least 200.[204] Algae can grow in water of all types, including wastewater and saline groundwater. When grown to produce oil, the yield is from 1000 to 6500 gallons per acre per year.

Compared to other purpose-grown fuels, algae possess the potential to produce a significant amount of fuel from a relatively small area. Chisti estimates that growing algae on 1 percent to 3 percent of the total U.S. cropping area would be enough to produce 50 percent of transportation fuel needs.[205]

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201 U.C. Riverside, "Converting Biosolids into Clean Synthetic Diesel Fuel," http://www.waterandwastewater.com/www_services/news_center/publish/article_001916.shtml

202 Gibbs, Holly, Proceedings of the National Academy of Sciences, Vol. 107 no. 37 August 31, 2010.

203 U.S. DOE 2010. National Algal Biofuels Technology Roadmap. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program. Visit http://biomass.energy.gov for more information.

204 Ibid, pages 76-81.

205 Chisti, Yusuf. 2007. Biodiesel from microalgae in "Biotechnology Advances", vol. 25, page 296.

The carbon intensity of algae-based fuels depends on the type of fuel produced. In September 2010, the National Academy of Sciences began a study of sustainable development of algal biofuels. The resulting report will include information about centralized and distributed production, land use, water use, nutrients, human health and safety, and potential toxicity. It will also recommend indicators and metrics to help assess sustainability. The report will not include an economic analysis because production has not yet reached commercial scale. The report is expected to be issued in early 2012.[206]

In 2010, the U.S. Department of Energy (DOE) Office of Biomass Program (OBP) published a National Algal Biofuels Technology Roadmap, which summarizes the state of technology for algae-based fuels, and the research and development needed to produce them at a commercial scale. OBP also released an Algae Biomass Supply Request for Information (DE–FOA–0000466) to gather information about supply systems and services for the production, handling, storage, transport, and delivery of algae biomass.

DOE contributed about $20 million for research and demonstration projects to develop algae feedstock, demonstrate technology to capture carbon dioxide for growing algae, and open a fully integrated algal biorefinery. In California, The Consortium for Algal Biofuels Commercialization, led by the University of California at San Diego, was one of the recipients ($9 million).

ARRA contributed more than $150 million for projects that experiment with growing algae in open ponds, develop an algae harvesting system, develop metabolic engineering and synthetic biology approaches to increase lipid production, produce a diesel substitute, and develop a systems approach for sustainable commercialization of algal biofuel. California companies receiving funding from ARRA are Sapphire Energy, based in San Diego ($50 million), and Solazyme Inc., based in South San Francisco ($22 million). USDA contributed a $54 million loan guarantee to construct a pilot algal biorefinery in New Mexico.

Venture Capital and Private Equity (VC/PE) firms contributed the most funding—more than $1 billion—mostly for projects that will experiment with commercial scale production. California companies receiving funding from VC/PE firms are Sapphire Energy ($100 million), Solazyme Inc. ($57 million), Aurora Biofuels, based in Alameda ($35 million), ExxonMobil and Synthetic Genomics, Inc. based in La Jolla ($600 million), and Green Pacific Biologicals, based in San Francisco ($225,000). The Program contributed about $300,000 for two projects that will experiment with growing algae at wastewater treatment plants.

The National Algal Biofuels Technology Roadmap describes a literature review of production costs, which reveals that many estimates are dated and use widely different basic assumptions. It notes, however, that "a combination of improved biological productivity and fully integrated production systems can bring the cost down to a point where algal biofuels can be competitive with petroleum at approximately $100 per barrel." [207]

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206 National Academies, "Project: Sustainable Development of Algal Biofuels," http://www8.nationalacademies.org/cp/projectview.aspx?key=49316

207 U.S. DOE 2010. National Algal Biofuels Technology Roadmap. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program, page 104.

Lundquist estimated costs for five production scenarios.[208] Depending on type and size of the plant, capital costs range from about $21 million to over $100 million. Land and pond construction are the most expensive capital costs, and staffing and maintenance are the most expensive operating costs.

Before converting algae to biofuel, the algae must be harvested, dewatered, and the oil or carbohydrates extracted. These processes are energy-intensive and expensive. Research is needed to develop cost-effective ways to prepare algae for conversion.

Pienkos lists 28 hurdles to algae cultivation, oil recovery, and biofuel production that include temperature control, carbon dioxide availability and transport, resistance to invasion in open ponds, and dewatering methods.[209] Additionally, Wijffels and Barbosa write that research is needed in biology, algae strain development, scale-up, biorefineries, and whole system design. They believe that production will be economically feasible only if combined with production of bulk chemicals, food, and feed ingredients. They estimate that sustainable, commercial production of algae-based biofuels will require another 10 to 15 years of development.[210]

The Energy Commission's PIER program is also supporting research into renewable algae as a drop-in transportation fuel, requiring no additional processing. The identified research solutions will develop alternative fuels designed for compatibility. In this respect PIER, is investigating large molecule alternative fuels (fuels that mimic gasoline, jet fuel and diesel), such as algae-derived fuels, but also including others derived from single cell organisms such as bacteria. Four research gaps affecting algae-derived fuels have been identified:

- Strain selection, i.e. finding, breeding, or genetically engineering the best oil producers.
- Growth media and containment, e.g., ponds and bioreactors.
- Oil separation technologies to separate algal lipids from water and biomass.
- Improved life cycle analysis (LCA) tools and method to better assess carbon emissions and land use impacts.

PIER has funded two competitively bid projects that address one or more of the research gaps. The first project is a $794,000 contract with NASA Ames to conduct research to develop and demonstrate the Offshore Membrane Enclosures for Growing Algae (OMEGA) system, primarily to address the issue of growth media and containment. OMEGA consists of lightweight, flexible, closed photo-bioreactors constructed of inexpensive plastic, with small sections of semi-permeable membranes for gas exchange and dewatering. They will be filled with nutrient-rich primary or secondary treated wastewater from municipal sewage treatment

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208 Lundquist, T.J., I.C. Woertz, N.W.T. Quinn, and J.R. Benemann, 2010. A Realistic Technology and Engineering Assessment of Algae Biofuel Production, page vii. http://works.bepress.com/tlundqui/5/. Accessed 11/9/2010.
209 Pienkos, Philip T, National Renewable Energy Lab, 2007. The Potential of Biofuels from Algae. Presentation given at the Algae Biomass Summit. www.nrel.gov/docs/fy08osti/42414.pdf, slide 16. Accessed 10/20/2010.
210 Wijffels, Rene H. and Maria J. Barbosa. 2010. An Outlook on Microalgal Biofuels in Science, 13 August 2010, vol. 329, pages 796-799.

facilities and the sealed enclosures will be inoculated with lipid-producing freshwater algae (mono-cultures or communities). Strains of algae will be cultivated that are able to thrive under local conditions and out-compete weed species in the wastewater. This project is addressing the growth media and containment research gap.

The second project is for the production of Soladiesel RD™, a renewable diesel, from cellulosic feedstocks. As a part of this project, the Energy Commission awarded $790,000 was awarded to Solazyme, Inc. to carry out the research to enable development of a commercial lipid biomanufacturing process using cellulosic feedstocks and heterotrophic algal fermentation. While Soladiesel RD™ could ultimately leverage existing industrial bioproduction facilities and commercial oil refineries to quickly prove commercial viability, the aim of this project is to research and develop the use of cellulosic biomass in Solazyme's algal biofuel technology. This project also addresses the strain selection and growth media and containment research gaps.

Future large molecule research efforts will continue to develop the economic and environmental potential of algae derived fuels. PIER will work with UC Merced to improve LCA tools and methods for algae derived fuels. PIER will also establish a California Initiative for Large Molecule Sustainable Fuels to perform research essential to developing the next generations of large molecule biofuel technologies and related materials. Research results should inform future investment recommendations.

Camelina

Camelina, also known as false flax or gold-of-pleasure, is a member of the mustard family and a distant relative to canola. It grows as an annual from one to three feet tall producing seed pods containing many small seeds (400,000 seeds per pound) with high oil content (35-38 percent and high in omega-3- fatty acid). As a comparison, the oil content of soybeans is 20 percent with soybeans.

Camelina is a short-seasoned, fast-growing crop planted in March and harvested in late July most years, even in Northern climates. It should be noted that camelina can grow in crop rotation with wheat. The plant can grow on marginal conditions with low inputs surviving on low moisture (10-17 inches of rainfall annually) with less nutrients than many other crops. However, the plant still requires management including herbicide application to help ensure successful establishment. Field trials in Oregon, Montana, and Idaho bear out the fact that camelina seed oil production is more cold-resistant that average biodiesel feedstock.

Camelina yields are roughly double that of soy and provide over 100 gallons of oil per acre. Early trial results have shown an increase in 15 percent production to wheat when rotated with camelina. According to Washington State University, Camelina provides 1,400 pound of seed per acre at 16 cents per pound or provides up to $224 per acre (compared to 28 bushels of wheat at $8.23 per bushel which produces $230 per acre).

Camelina has the potential for use as cattle feed supplement, feedstock for biofuel and bio-lubricant, and soil nutrient enhancer. Primary energy market potential exists as a feedstock for aviation biofuel as it can reduce emissions nearly 85 percent over conventional fuel. .

Great Plains and Sustainable Oils have been identified as early commercial ventures in the development of camelina as an aviation biofuel. AltAir has a contract with 14 airlines to produce 100MGY of diesel and renewable jet fuel at Tesoro facility in Washington. Sustainable Oils has a partnership with BioJet to produce up to 200 MGY plus 65 MGY co-products, and 2.3 million tons per year camelina meal for animal feed.

There are key issues to address in expanding the commercialization of camelina as a feedstock, including educating growers to new commodity markets, incentiving aviation in California, and focusing camelina development in cooler climates of the state.

Corn

The most rapidly increasing use of corn in the United States has been as a feedstock to produce fuel ethanol, rising from 12.8 percent of total supply in 2005 to nearly 36 percent today.[211] Over the same period of time, corn for animal feed and residual use has declined from 57.6 percent during 2005 to 39.3 percent today.

Corn kernels are used in biorefinery fermentation facilities to produce conventional ethanol from the starches in the kernel. Oil from the kernel can now be removed and used as a biodiesel feedstock with a very low carbon intensity value. Corn stover (consisting of the stalks, leaves, husks and cobs remaining after harvesting) can be utilized in a cellulosic conversion process to produce ethanol with lower lifecycle carbon emissions. The U.S. corn ethanol industry is becoming increasingly sophisticated in its ability to use all parts of the corn plant for fuel and feed production.

After starches are removed during ethanol fermentation, high protein distillers grains in wet or dry form are separated and sold as animal feed. Approximately one-third of every bushel of grain processed into ethanol is returned to the animal feed market in more concentrated forms as distillers grains, corn gluten feed, or corn gluten meal. Corn bi-products are also used for fertilizer and soil amendment.

U.S. corn grain production is estimated at 12.4 billion bushels in 2010, down from the record 13.1 billion bushels for 2009, while it was 13.0 billion bushels in 2007. U.S. corn yield was 158.2 bushels per acre in 2010, down from a record 164.7 bushels per acre in 2009. Per acre productivity for corn production has increased from about 90 bushels per acre in the early 1980s to 158 bushel per acre in2010. Total U.S. acreage to corn was about 88 million acres in 2010, with most production occurring in Midwest states. California has about 625,000 acres allocated to corn, which serves the sweet corn market and local silage demand. Nationally, per acre productivity is projected to increase steadily at a rate of two bushels per acre per year. Productivity gains are a result of continuing improvements in plant genetics, machinery and tillage practices.[212] The consumption of corn for U.S. ethanol production was 41.6 percent during 2010.[213]

211 USDA Economic Research Service statistics. Total supply includes production, imports, and changes of inventory levels.
212 USDA Economic Research Service, “Corn Market Outlook,” http://www.ers.usda.gov/Briefing/Corn/2010baseline.htm
213 During 2010, 4.724 million bushels of corn were converted to fuel ethanol out of a total of 11.346 million bushels of total use. Energy Commission analysis of U.S. Department of Agriculture statistics.

The carbon intensity (CI) for Midwest biorefineries using conventional ethanol processing of Midwest corn is 98 grams of CO2-equivalent per mega joule of energy (g CO2e/MJ) with 30 g CO2e/MJ attributed to indirect land use change (ILUC). California-produced corn ethanol using Midwest corn feedstocks has a CI of 81 g CO2e/MJ with 30 g CO2e/MJ attributed to ILUC. This 18 percent lower carbon intensity value for California-produced ethanol using Midwest corn feedstocks is a result of modern biorefineries using state of the art process efficiencies and the use of natural gas and California's relatively green electricity mix as process energy sources. Midwest biorefineries rely on coal for process energy.

Sustainability concerns for first generation corn ethanol tend to be expressed in terms of indirect land use change,[214] effects of demand for corn ethanol on global corn commodity prices, and water use for corn cultivation and ethanol refining. The Energy Commission plays an active role in investigating sustainability issues associated with alternative fuel production. Professor Wally Tyner of Purdue University is an original author of the Global Trade Analysis Project (GTAP) model used by the Air Resources Board to estimate indirect land use change numbers for the LCFS. His 2010 revision to the model produced a range of results one third to one half lower than the current figure of 30 g CO2e/MJ. The Indirect Land Use Expert Workgroup convened by the Air Resources Board during 2010 reviewed Professor Tyner's revisions and recommended that the ARB adopt a mid-range scenario that would result in an approximate reduction of the ILUC factor by 50 percent.[215] Energy Commission staff participated in this Expert Workgroup.

Various concerns regarding increased water use and higher fertilizer application rates associated with corn have been voiced by some stakeholders. Based on the most recent agriculture census by the U.S. Department of Agriculture (2007), the majority of corn is grown without the use of any irrigated water, solely dependent on rainfall during the growing season. In 2007, only 15.3 percent of corn acres were irrigated with the balance (84.7 percent) receiving no irrigated water.[216] It is not known if expanded production of corn will occur as a result of an

214 The concept of ILUC is that for each acre of food or forage replaced by a bioenergy crop, somewhere in the world, a landowner will indirectly make an economic decision to clear virgin land to produce more food, and release additional carbon from the surface vegetation and soil. Some portion of this carbon should then be attributed to biofuels production in a carbon accounting system. This phenomenon is sometimes called "market mediated effects." ARB added ILUC carbon intensity estimates to direct emissions fuel pathways for purposes of the LCFS regulation to conform with results of the Searchinger paper in Science from 2008, which found that corn ethanol had nearly twice the carbon intensity of petroleum when ILUC was factored in (~200g CO2e/MJ total carbon). Current ILUC estimates for corn ethanol production are much lower. A copy of the Serchinger paper may be viewed at the following link: http://www.princeton.edu/~tsearchi/writings/SupportingMaterials.pdf

215 ARB Staff Cover Report on the Results of the Indirect Land Use Expert Workgroup to the Air Resources Board, January, 2011.

216 Corn using irrigated water totaled 13.16 million acres in 2007, while non-irrigated corn amounted to 73.09 million acres. Since irrigated corn has a higher yield, the percentage of corn produced from irrigated acres is slightly higher, approximately 16.9 percent for the same year. *2007 Census of Agriculture*, United States Department of Agriculture, Table 32, page 26, updated September 2009. A link to the document is as

even higher ratio of irrigated acres over the forecast period. Assuming the ratio remains fairly constant, increasing corn production due to higher mandated ethanol demand should primarily occur through expansion of dry cropping, rather than through increased irrigation. With regard to fertilizer use, Energy Commission staff examined USDA statistics and noted that the application rate per acre of corn for nitrogen has increased 6.2 percent between 1980 and 2005, while the average corn yield has increased 62.5 percent over the same period.[217] The continued improvement of corn yields is primarily a consequence of other improvements unrelated to increased use of nitrogen per acre.

Corn ethanol is imported from major ethanol production facilities in the mid-west via rail cars to major California ethanol distribution terminals (Carson or Albany). This ethanol is used as an oxygenate for California reformulated gasoline (RFG), and is currently blended at the E10 (10 percent) level. During 2009, 95 percent of California's 962 million gallons of ethanol use was imported from outside the state via rail cars, 4 percent produced from California facilities and the remaining 1 percent imported from foreign sources via marine vessel. During 2009, the emerging E85 retail fueling market in California dispensed about 1,173,025 gallons.

There are five corn-based ethanol plants in California, with a combined production capacity of 250 million gallons per year. Estimated capital cost to construct these plants is about $500 million in private capital. Direct employment when the five plants are operating at full capacity is estimated to be 175. Most of these plants have been idled since January of 2009 due to poor operating economics and high debt loads. Until the LCFS begins in earnest, there is no market mechanism to value and remunerate California producers for their lower carbon ethanol products. In early 2011, the Energy Commission allocated $6 million from the California Ethanol Producer Incentive Program (CEPIP) to provide operators of existing corn ethanol production plants in California with temporary financial assistance, as funding is available, during periods of difficult economic operating conditions that would be repayable under specifically identified favorable market conditions. This program also will stimulate operational improvements at existing ethanol facilities and the use of advanced process technology to convert cellulose and other low carbon feedstocks. Two of these facilities are currently operating using mid-west corn.

The federal Renewable Fuel Standard (RFS2) and California's Low Carbon Fuel Standard (LCFS) will impact the demand of and distribution infrastructure facilities for ethanol. The federal program of mandated renewable fuel use is expected to significantly increase ethanol use in California such that gasoline demand will be decreased to a greater extent than demand reductions forecast as a result of higher corporate average fuel economy standards. In addition, due to the current state ethanol blending limit of 10 volume percent in gasoline, the RFS2 will likely result in significantly greater use of E85 so that obligated parties achieve their "fair share"

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follows: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

217 Most recent complete year of fertilizer data for U.S. corn acres is 2005. Nitrogen application for fertilized corn was 130 pounds per acre in 1980 and 138 pounds per acre in 2005. *U.S. Fertilizer Use and Price*, USDA Economic Research Service, Table 10, updated November 20, 2008. The data is available at: http://www.ers.usda.gov/Data/FertilizerUse/Tables/FertilizerUse.xls

compliance levels. The 2009 transportation fuels forecast by the California Energy Commission estimated that E85 demand levels would increase from 1.1 million gallons in 2010 to 1,725 million gallons in 2020 and 2,262 million gallons by 2030 under the Low Demand Case for gasoline.[218]

The state LCFS may not appreciably alter the demand forecast for ethanol, rather will necessitate the use of specific types of ethanol with lower carbon intensity relative to Midwest corn-based ethanol supplies. Although commercial production levels of cellulosic ethanol have yet to be achieved by the market, low-carbon intensity ethanol of this kind will eventually be needed to help refiners and marketers to achieve LCFS compliance in the latter years of the regulation.

Farmed Tree Products

The Energy Commission is further investigating this feedstock.

Grasses

Grasses have been grown in the US for various purposes including turf, cattle feed, and in co-firing power plants. Predominant grasses for energy, in particular as a biofuel, include switchgrass, miscanthus, and bermudagrass. All three of these grasses are perennials that have different characteristics related to planting practice (seed, stolons, rhizomes), nutrient requirement (varying macronutrient levels), harvesting (single or multiple), and yield (length of growing season, water availability).

Most of the grasses are native to Texas, require several years to reach maximum maturity, and have an optimum daytime temperature requirement above 75 degrees. Grasses can also suffer from insect damage if proper management practices are not implemented.

Early switchgrass field trials suggests a technical yield of 20 tons per acre and an actual yield of 10-12 dry tons per acre in the Imperial Valley of California. Bermudagrass production in California is largely harvested as sod for turf purposes as genetically modified strains typically produce sterile seed.

The California Biomass Collaborative has identified Bermuda and other grasses as strong candidates for cultivation in fallowed agricultural lands that are no longer arable due to selenium and boron concentrations, or due to reductions in available irrigation water. The grasses could remediate soil conditions in areas like the western San Joaquin Valley, and provide a feedstock resource for cellulosic ethanol. [219]

The costs of switchgrass production approach $225 per acre in total costs. Grass is baled at a cost of $30 per ton or $300 per acre.

According to a USDA report, grasses have been identified as a carbon neutral plant. As a biofuel, grasses can be source for ethanol production via cellulosic conversion technology.

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218 *Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report*, Final Staff Report, California Energy Commission, report number CEC-600-2010-002-SF, May 2010, page 72.
219 Professor Steven Kaffka, UC Davis and California Biomass Collaborative, Presentation to Energy Commission during AB 118 Regulatory Proceedings for sustainability, 2009.

Issues identified with grasses as a feedstock include the need to effectively establish itself as a bioenergy crop, biochemical conversion costs are high, and thermochemical conversion technology requires more development.

Palm Oil

Palm oil, one of the world's largest agricultural commodities, is widely used for a number of food and cosmetic purposes, including as a renewable diesel substitute. Palm oil is projected to make up 34-46 percent vegetable supply in 2010 to 2020. [220] A palm plantation typically produces 435 -630 gallons of oil per acre, compared to soybean oil's 74 gallons/acre.[221] Palm oil yields are the second most productive fuel volume crop. (Sugar cane produces roughly 800 gallons/acre.[222]) In 2009 over 50.5 million metric tons of palm oil was produced; 20 percent of this volume was estimated to be used in non-food purposes (such as renewable fuel).[223] This potential renewable fuel volume represents over 2.9 billion gallons. For purposes of comparison, California uses 3 billion gallons of diesel fuel per year.

Malaysia and Indonesia account for 83 percent of palm oil production and 89 percent of global exports. In 2009, Indonesia became the largest producer of palm oil, producing more than 20.9 million metric tonnes,[224] while Malaysia produced 19.8 million metric tonnes.[225] (One ton is approximately equivalent to 5.6 billion gallons.) Extremely high palm oil production growth rates have been sustained over the past ten years in Malaysia and Indonesia. These historic growth rates are a result of strong global vegetable oil demand and significant political and economic reforms established by the government following the Asian Financial Crisis in the late 1990's. Continued palm oil production growth rates are expected for at least two more decades due to improved crop yields from existing fields, new maturing plants starting production, and new crop plantations being built.

Palm oil costs vary over time, and can be affected by commodity prices for other bio-oils, international tariffs, and international events (including natural disasters). A refiner's interest in palm oil is also directly related to the price of petroleum crude oil, and is also impacted by the costs and savings associated with any GHG regulations. From 2008 to 2010, Palm crude oil commodity prices raised from $438-$1,200 per metric tonne.[226] These palm prices represent $1.50 to $4.25 per gallon of feedstock to a potential fuel producer. Additional costs to receive, transport, and process the feedstock would raise the cost 30-45 percent.

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220 Sime Darby Plantation, "Palm Oil Industry in Malaysia," Skills & Knowledge for Sustained Development in Africa, June 24, 2009.

221 Biofuels: Production, Use and Its Implications on GHG emission, Dato' Dr. Mohd. Basri Wahid, Malaysian Palm Oil Board. Cites 3.8 tonnes per hectare per year.

222 Energy Commission staff analysis of published production yields.

223 Sime Darby Plantation, 2009.

224 USDA Foreign Agricultural Service, "Indonesia: Palm Oil Production Prospects Continue to Grow," December 31, 2007, http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/

225 Economics and Industry Division Statistics, & Oil World Annual (2000-2009).

226 Index Mundi, "Palm Oil Monthly Price," http://www.indexmundi.com/commodities/?commodity=palm-oil&months=60

Worldwide, an increasing number of refineries are demonstrating interest in palm oil as a feedstock. In the summer of 2010, Bloomberg reported Europe's first new palm oil plant in Liverpool. This palm oil refinery supplies 40 million tons of palm oil per year, or theoretically 11.3 billion biofuel gallons.[227] Additionally, two new renewable diesel plants using Neste oils' biomass-to-liquid process are coming on line in 2011 one in Rotterdam and Singapore. Each will consume 800,000 metric tons of palm oil and produce 226 million renewable diesel gallons per plant. These two plants combined demand represent one year's production capacity growth from Indonesia.

Oil palm cultivation and processing, like other agricultural and industrial activities, raises environmental issues and sustainability concerns. Forest clearing, land degradation and loss of fertility caused by soil erosion is a major problem in many parts of the world, and is especially rampant in the tropics. A recent paper by Stanford researcher Holly Gibbs documents forest clearing and land conversions in Asian and Southeast Asian countries where oil palm plantations expanded rapidly to meet growing global demand for palm oil. Indonesian palm oil plantations expanded from 2 million hectares to 5 million hectares between 2000 and 2008. For Southeast Asia as a whole, plantations increased from 11 million hectares to 17.4 million hectares between 1980 and 2000; with oil palm plantations accounting for 80 percent of the increase.[228] Koh and Wilcove found that half of the land cleared for plantations between 1990 and 2005 in this region came from tropical forests. [229]

In response to the urgent and pressing global call for sustainably produced palm oil, the Roundtable on Sustainable Palm Oil (RSPO) was formed in 2004 with the objective of developing and implementing global standards for sustainable palm oil through credible global standards and engagement with stakeholders.[230] In 2008 the first Malaysian palm oil plantation was certified by the RSPO's Certificate of Conformance. By the end of 2010, there were 22 growers, 81 palm mills RSPO certified, representing 3.5 metric tons, or 17 percent of the Malaysian palm crude oil.[231]

Additionally, New Britain Palm Oil Limited (NBPOL) has developed an Environmental Management System to help the company to minimize its effects on the environment. The company is using the international standard for environmental management, known as ISO 14001 (1996), as the vehicle to deliver this system and in May 2004 NBPOL achieved accreditation. This standard is universally employed and recognized as a measure of quality in establishing a systematic approach to environmental management. This recognition will foster environmental confidence and demonstrate environmental responsibility to the people who buy palm oil.

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227 New Britain Palm Oil Limited, "Latest News," http://www.nbpol.com.pg/n_latest_news.php
228 Gibbs, 2010.
229 Koh and Wilcove, Conservation Letters, 2008.
230 RSPO stakeholders include oil palm producers, palm oil processors or traders, consumer goods manufacturers, retailers, banks and investors, environmental or nature conservation organizations, and social or developmental organizations.
231 RSPO Certified, "Growers Certification," http://www.rspo.org/?q=page/508

An initial estimate for the carbon intensity of palm oil used for biodiesel or renewable diesel determined an 88 percent GHG reduction, but this did not account for indirect land use emissions estimates.[232] The Air Resources Board has not yet adopted a Life Cycle Analysis value for palm oil for the Low Carbon Fuel Standard. Current ILUC estimates for soy (62 gCO2-e/MJ) and Brazilian sugarcane (46 gCO2-e/MJ)[233] indicate that the ILUC value for Southeast Asian oil palm may be comparably high. Worst case examples include peat forest land use at 45 tonnes CO_2e per hectare year, and rubber plantation-based palm oil plants at 7 tonnes CO_2e per hectare year. Better case examples include natural forest, oil palm (food) and tropical fallow sources, at 2, 6, and 8 tonnes CO_2e per hectare year respectively.[234] These figures indicate that multiple fuel pathway estimates may be warranted for Southeast Asian oil palm in order to create positive market incentives for oil palm from older, converted cacao plantation, and negative incentives for palm oil from new plantations from recently cleared tropical forests.

In addition to palm oil, approximately 60 million metric tons of palm plant waste is created annually in the production of palm oil. This biomass could theoretically be converted via second-generation biofuel processes to yield 1.0 billion biofuel gallons.[235] The additional biofuel or bioenergy would be counted in future LCAs to yield greater GHG benefits over time.

Soybean

For 20 years soybean oil has been the feedstock of choice to produce biodiesel in the USA. In the past, soybean oil has been used for 30-60 percent of California's biodiesel supply. Soybeans are the predominant row crop grown in the USA for biodiesel fuel production; canola, palm, and rapeseed are similar alternatives gown worldwide for the biodiesel fuel. All are generally interchangeable in practice and share some market price linkages.

California does not grow soybeans and for the last three years no soybean acres are evident by the Agriculture Statics Board January 2010 report.[236] Soybean oil used in California for biofuel is brought in by trains at a cost of 15-45 cents per gallon, or is trucked in. Soybeans are predominantly grown for the meal and protein. The byproduct of soybeans is used to make biodiesel. Most (85 percent) of the soybean is used as meal, and the other 15 percent is used for ink, plastics, and fuel. Historically, soybeans were grown and genetically engineered for to maximize meal, not plant oil. Now, genetic research is seeking to maximize the oil production aspects to expand this crop for fuel markets.

232 Full Fuel Cycle Assessment: Wells-To-Wheel Energy Inputs, Emissions, and Water Impacts, California Energy Commission, Consultant Report, 8/1/2007.

233 ARB, "Proposed LCFS Look Up Tables for the February 24, 2011 Board Hearing, http://www.arb.ca.gov/fuels/lcfs/010611lcfs_lutables.pdf

234 Reinhardt, Guido, "LCA of Biofuel Oil Crops: State of the art balancing scientific accuracy with the demands of policy makers," International Palm Oil Life Cycle Assessment Conference Kuala Lumpur, Malaysia, October 19-20, 2009.

235 Global Business Leaders, Forum 2010, Plenary 6: Creating a Sustainable Energy Mix, M.R. Chandran Advisor to EB, RSPO, KL Convention Centre, Kuala Lumpur, November 22-23, 2010.

236 US Departmet of Agriculture, National Agriculture Statistics Service, "Crop Production 2009 Summary," January 2010.

Of all the food crops considered for bio-fuels, soybeans have the lowest fuel yield per acre. Soybeans yield approximately 75 biodiesel gallons per acre, as compared to 450 gallons per acre for corn-to-ethanol, or 635 gallons per acre from palm oil.[237] As a consequence of the low oil yield per acre, soybean oil is not envisioned to be a major domestic transportation fuel source beyond a 5 percent level.[238]

The production volume of soybean oil has been steadily growing and accelerating since a federal $1.00 per gallon subsidy was enacted in 2004. Soybean oils provide a steady oil quality, desired by biodiesel producers, major oil companies and marketers for its consistent qualities and good cold weather flow properties. Soybean oils produce a better cold weather fuel than palm oil feedstocks.

America is a significant world soybean producer. Sustainability practices are considered as they apply to US grown crops. Since 1910, the total planted principal crops in the United States, harvested acres have remained the same.[239] Principle crops include 25 crops, such as, corn, canola, and soybeans. Consequently, there is no historical evidence that more total agriculture acreage has been required to increase existing soybean oil production, which started in 1990 at zero gallons and grew to nearly 700 million gallons by 2008. However, there is evidence that planted acres for soybean increased from 24,440,000 acres in 1960 to 77,451,000 acres in 2009.[240]

In 2010, the U.S. EPA adopted a GHG emission reduction 57 percent for soybean oil converted to biodiesel or renewable diesel, including indirect land use effects. For California, ARB adopted a 12 percent GHG benefit; direct carbon emissions from soy are 21 gCO2-e/MJ, while the indirect land use emissions estimate is 62 gCO2-e/MJ. This high ILUC estimate reflects large scale forest clearing in countries like Brazil for new soy plantations, where soy plantings increased from 13 million hectares to 21 million hectares in just 10 years.[241] ;

There are no known projects in California pursuing soybean or canola farming. The closest plant that is grown in California that produces an oil is sunflower, of which 34,000 acres were planted in 2009, and none were reported in 2007 and 2008. [242] More critically, California lacks soybean crushing facilities, and the crushing process uses hexane; a volatile petrochemical that California Air Quality Districts have raised issues with.

International commodity prices for soybean oils, canola, rapeseed and palm oils are somewhat linked in the market. During 1996-2006, soybean prices ranged from $50 to $110 per barrel, during the same time crude oil was $20-$40 per barrel lower. Absent governmental intervention soybean oil does not compete well with petroleum prices. Historically, soybean market prices

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237 Staff assumes soybean values of; 51 bushels/acre, 11.28 pounds of soybean oil per bushel, and 7.8 pounds of oil/gallon.

238 National Biodiesel Board has a 5 percent biodiesel displacement goal by 2015.

239 US Department of Agriculture, National Agricultural Statistics Service, "Crop Production Historical Track Records," April 2010, http://usda.mannlib.cornell.edu/usda/current/htrcp/htrcp-04-12-2010.txt

240 Ibid.

241 Gibbs, 2010.

242 US Department of Agriculture, National Agriculture Statistics Service, "Crop Production 2009 Summary," January 2010.

are more volatile and higher priced than crude oil prices. The Federal $1.00 per gallon incentive is powerful but not as powerful as the food markets strength. Worldwide interest and policies pursuing renewable and GHG reduction have spurred the supply and the cost to secure most all plant oils, and are likely to continue this trend.

Sugar Beets

Sugar beets have been grown in California from the 1950s to present times, primarily in the San Joaquin and Imperial Valleys, as a feedstock for sugar mills and as a supplemental cattle feed.[243] California-grown sugar beets have very high per acre yields and sugar content, and is highly regarded as a potential ethanol feedstock. Sugar beet production in California peaked in 1964 and 1971 with about 350,000 acres of production, but current production is about 40,000 acres. Average yields can be as high as 35 tons per acre (California corn yields are 4.8 tons per acre), with an ethanol conversion factor of about 25 gallons per ton. Production on 200,000 acres could yield about 170 million gallons per year (MGPY) of ethanol. As a co-product, sugar beets yield 18 to 25 tons of beet pulp per acre, which can be used as an animal feed supplement.

No sugar beets are in use as a biofuels feedstock in California. Several large and modern ethanol biorefineries (90 MGPY) have recently been built in Germany using sugar beets as the feedstock. In California, UC Davis has evaluated their potential as a feedstock and has conducted crop trials. Professor Steven Kaffka of the Department of Agronomy has led much of this research.[244] The California Department of Food and Agricultural is further evaluating sugar beet potential through a $1 million research agreement for energy crop assessment with PIER.

The Energy Commission is funding the Mendota Beet Cooperative's feasibility study of an integrated biorefinery through a $1.5 million ARFVT grant. The Mendota project would use 840,000 tons of sugar beets per year to produce about 33.5 million GPY of low carbon ethanol (45 percent below the petroleum baseline). The Mendota Beet Cooperative estimates cultivation on 11,000 to 22,000 acres of farmland that has either been used historically for sugar beet production, or that is currently fallow.

Sugarcane

While primarily considered a tropical crop, a variety of sugarcane known as energy cane may be well suited for cultivation in the Imperial Valley. Initial field trials through UC Davis indicate extremely high yield potential of 1,200 to 1,400 gallons per acre (as compared to 870 gallons per acre for sugar beets or 459 gallons per acre for corn).[245] Energy cane could be grown on non-prime agricultural soils in the Imperial Valley that are currently fallow, or that are used for forage grasses such as Bermuda grass, which is used for dairy production. While the potential for high productivity is evident, energy cane requires high volumes of irrigation water of about 8 to 9 acre-feet per year. This is comparable to current Imperial Valley alfalfa cultivation, but higher than the 2 acre-feet per year required for sweet sorghum cultivation. A

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243 Robert Williams and the California Biomass Collaborative, "California Biofuels Potential," Draft Consultant's Report, unpublished, 2007.

244 Steven Kaffka, Presentation at the Energy Commission's Staff Workshop for the 2010-2011 Investment Plan (Biofuels Waste-Stream, Purpose Grown, and Bioengineered Feedstocks, and Production Technology and Economics), September 14-15, 2009.

245 California Biofuels Potential, Draft Consultant's Report.

UC Davis Biomass Collaborative draft report estimates potential ethanol production of up to 200 MGPY if energy cane were produced on 100,000 acres – 20 percent of the irrigated 500,000 acres of farmland – currently in production in the Imperial Valley.[246] Such production would not affect primary food crop production on prime soils.

Proposals for ethanol production from energy cane in California are modeled after state of the art practices developed for Brazilian production. All parts of the plant would be used; juice for primary fermentation, with the plant remainder (bagasse) being used for process energy for combined heat and power, green energy production, or building products. The carbon intensity value for ethanol from energy cane could be as low as 4 gCO2-e/MJ, or 95 percent below the gasoline baseline.[247]

The Energy Commission received several proposals for energy cane to ethanol production in response to the Energy Commission's PON-09-604 solicitation, released in April 2010. This solicitation was extremely competitive, and the Commission was able to fund only 12 of the 44 proposals received.

Sweet Sorghum

Sweet sorghum is a variety of grain sorghum with very high sugar concentrations in its stalk. It has not been grown commercially in California, although numerous field trials have been conducted in Colusa and San Joaquin Counties.[248] It has lower water requirements than California-grown corn (2 acre feet per year as opposed to 3 acre feet per year for corn). Sweet sorghum will grow on soils with salinity and boron contamination that are unsuitable for food crops, which makes it promising for cultivation in the San Joaquin Valley, which suffers from selenium contamination from long-term irrigation.

Sweet sorghum plants can be pressed to extract the sugar juice, which is then fermented to form ethanol. Initial yield estimates are 70 gallons per acre to as high as several hundred gallons per acre. As with sugarcane, the plant remainder can be used as an energy resource (bagasse), as a cellulosic fuel feedstock, or further broken down to form a variety of feed materials, pharmaceuticals, or building materials.

The Energy Commission is funding the Great Valley Energy Center sweet sorghum feasibility project through a $1.9 million ARFVT grant. This project will assess multiple sweet sorghum varieties through field trials in Kern County. Great Valley's approach is to produce ethanol from the sorghum juice, and assess the feasibility of producing building products from the plant remainder using the Tilby Press, which was developed in Australia to break down sugarcane stalks into beneficial co-products.

Fuel Conversion Processes

The Energy Commission is developing detailed assessments for major biofuel conversion processes. These assessments will expand upon the tables in Appendix D.

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246 Ibid.

247 California Ethanol and Power, "California-Produced Sugarcane Ethanol to Be Responsible for Less Greenhouse Gas Emissions Than Gasoline and Brazilian Ethanol," http://www.californiaethanolpower.com/pdfs/CEP-Press-Release-Feb20-2009_Final.pdf

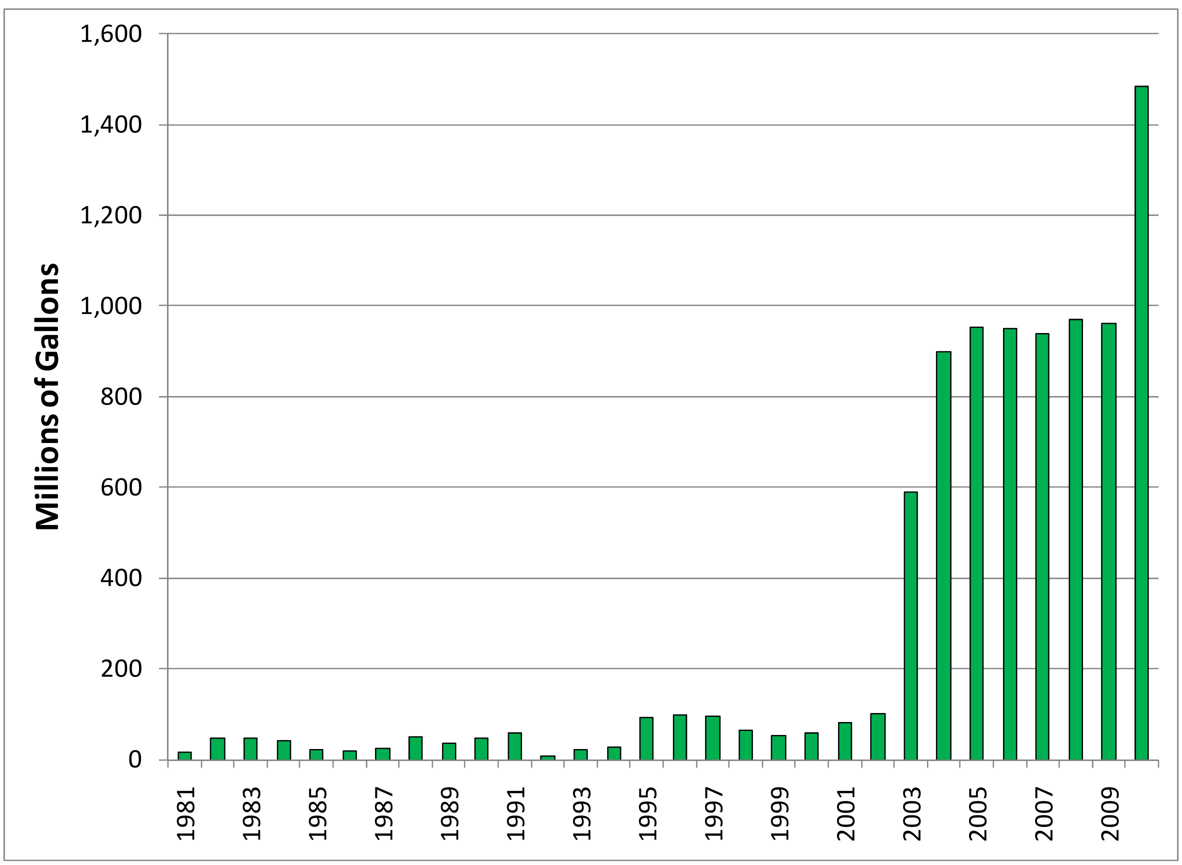
248 Phillip Trainer, Presentation at Energy Commission Biofuels Workshop, September 14-15, 2009.

Ethanol

Ethanol is the most prominent alternative fuel produced and consumed in the United States and California. Between 1997 and 2010, nationwide production has increased more than 19.5 percent per year, with approximately 13.1 billion gallons of ethanol produced in 2010. Similar increases in ethanol production were seen within the state of California throughout the previous decade. Between 2004 and 2008, California ethanol production capacity grew at an average annual rate of over 55 percent to its current capacity of 240 million gallons per year. However, according to the Renewable Fuels Association, roughly 75 percent of the country's ethanol production capacity remains in the Midwest, with the remaining 25 percent scattered nationwide.

Despite its relatively small production of ethanol, California consumes a significant amount of the fuel each year. In 2003, California ethanol consumption jumped from a little over 100 million gallons to a little under 600 million gallons, due to its replacement of methyl tertiary butyl ether (MTBE) as a prominent gasoline additive. Consumption jumped another 44 percent in 2004 and almost 10 percent in 2005, and remained fairly steady until 2010, when the ethanol blend in California reformulated gasoline increased to 10 percent, and total ethanol use grew to nearly 1.5 billion gallons. However, California ethanol facilities contributed less than four percent of the state's needs during 2010. Figure 1 shows California ethanol consumption.

Figure 1: California Ethanol Consumption, 1981-2010



Source: California Energy Commission and Energy Information Administration

A variety of federal and state policy mandates will necessitate an increase in the consumption of renewable fuels through this decade. Given that California is approximately 11.5 percent of the

U.S. population, California's "fair share" consumption of biofuels under the federal RFS2 is expected to be approximately 3 billion gallons.[249] At the state level, the ARB's LCFS outlines four scenarios for achieving GHG emission reductions from gasoline, each of which prominently includes contributions from ethanol. These scenarios include a broad range, from 2.2 billion gallons to 3.1 billion gallons per year by 2020.[250] The state's Bioenergy Action Plan establishes a 2 billion gge target for biofuel consumption by 2020, in which ethanol is likely to feature prominently. The Bioenergy Action Plan also calls for 20 percent of the state's biofuel consumption to be met by in-state resources. For ethanol, this will entail approximately 500 million gallons per year in additional production (in addition to the full resumption of production at existing plants).[251]

Currently, California's ethanol is a mixture of ethanol produced in-state, in the Midwest, and from foreign sources. California is uniquely positioned, however, to use vast low-carbon feedstocks and to produce ethanol from feedstocks other than corn. For example, California has significant waste streams from the agricultural, municipal, and forest sectors that are available for use as feedstocks for advanced biofuels with low-carbon content.[252] Specialty bioenergy crops such as cane, sweet sorghum, and perennial grasses can also be grown on marginal soils to produce very low-carbon biofuels (with 75 percent and higher GHG reductions from the petroleum baseline).

However, at this time, these types of renewable fuel technologies have not been demonstrated to be commercially successful. The U.S. EPA issues renewable volume obligations each December to provide guidance on the mandated minimum volumes of renewable fuels by various categories for the upcoming calendar year. Over the last two years, the EPA has significantly reduced the cellulosic renewable fuel requirement due to the lack of production capacity in the United States, most recently reducing the RFS cellulosic requirement for 2011 down from 250 million gallons to 6 million gallons.

To encourage further development of low-carbon liquid fuel options, the Energy Commission intends to allocate $7.5 million for the development of new production facilities that can convert sustainably-derived cellulosic feedstocks into a low-carbon ethanol.

Additionally, process energy efficiency measures and alternative fuels used for process energy can further reduce the GHG emissions from California ethanol. At the Energy Commission's *2010-2011 Investment Plan* Biofuels Workshop, several project developers described strategies to

249 Orta, Jason, Zhiqin Zhang, and et. al. 2010. 2009 Progress to Plan - Bioenergy Action Plan for California. California Energy Commission. CEC-500-2010-007.

250 Air Resources Board, "Proposed Regulation to Implement the Low Carbon Fuel Standard: Volume II, Appendices," March 5, 2009, http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol2.pdf

251 California Energy Commission, "2009 Progress to Plan - Bioenergy Action Plan for California," http://www.energy.ca.gov/2010publications/CEC-500-2010-007/CEC-500-2010-007.PDF

252 *An Assessment of Biomass Resources in California, 2007* Draft Report, PIER Collaborative Report, March 2008. Using a California Biomass Collaborative average value of 82 gals of ethanol derivable from each BDT of a mix of biomass wastes and residues yields a technical potential in 2010 of 2.9 billion gallons of ethanol.

produce very low-carbon intensity biofuels (with more than 80 percent reductions from the CaRFG baseline) at competitive prices in California. These strategies include:

- Fractionation of feedstocks into multiple value-added products including ethanol, renewable diesel, green electricity, and other co-products,
- Development of specialty bioenergy feedstocks such as energy cane, sweet sorghum and perennial grasses that can be grown on marginal, non-food crop soils, and
- Capital investments to increase biorefinery production outputs to meet shifting and new market demands, similar to the production strategy used by petroleum refiners.[253]

However, a lack of capital and debt financing is impeding biofuel plant development and upgrades at existing plants. If capital and debt financing were readily available, California's existing and planned plants could move forward to initiate use of California's biomass wastes and other alternative low carbon feedstocks. Many in-state developers of advanced biofuels projects are positioned to provide technology specifically designed to convert agricultural, forest, and municipal waste streams to transportation fuel. However, the present poor operating economics associated with these potential projects is the primary reason that financing has not been forthcoming.

The profitability of the U.S. ethanol industry has fluctuated with gasoline price and demand as well as corn prices. Consequently, in recent years the industry has had very narrow margins, as the impact of the global economic slowdown and decline in oil demand and prices, as well as upward pressure on corn price, have made survival more difficult. This poor performance has occurred despite a number of policy actions that support the ethanol industry, including:

- The Volumetric Ethanol Excise Tax Credit: a $0.45 per gallon excise tax credit for refiners and blenders. It is set to expire in 2011.
- The Secondary Tariff on Ethanol: a $0.54 per gallon ethanol import tariff intended to support domestic production. It is set to expire in 2011.
- The Small Ethanol Producer Tax Credit: a $0.10 per gallon tax credit for ethanol production up to 15 million gallons. The credit is available only to small scale ethanol producers with an annual production capacity of no more than 60 million gallons. It is set to expire in 2011.
- The Cellulosic Biofuel Producer Tax Credit: a $1.01 per gallon tax credit for producers of cellulosic biofuel, intended to spur cellulosic production. It is set to expire in 2012.

253 Testimonies of David Rubenstein of California Ethanol and Power, Brian Pellens of Great Valley Energy, and Bob Walker of Swan Biomass, AB 118 2010-2011 Investment Plan Workshop, September 14-15, 2009, California Energy Commission, Sacramento California.

California Ethanol Producer Incentive Program

The Energy Commission developed the CEPIP to provide operators of existing corn ethanol production plants (minimum 10 million gallons per year) in California with temporary financial assistance during periods of difficult economic operating conditions. Currently, five plants are eligible for this assistance. This funding would be repayable under specifically identified favorable market conditions. The CEPIP is designed to stimulate operational improvements at existing ethanol facilities and the use of advanced process technology to convert cellulose and other low carbon feedstocks. The objectives of the CEPIP are to increase statewide biofuel production, retain and create California jobs, and reduce greenhouse gas emissions. CEPIP was provided $6 million in initial funding, with the understanding that funding could be increased by $9 million.

The CEPIP requires participants to comply with biorefinery operational enhancement goals (BOEG) in one of two ways. The first BOEG is based on the participant's reducing the carbon intensity value of their produced fuel by at least 10 percent, relative to the default value adopted under the LCFS for their particular process application and type of feedstock. The second BOEG requires the biorefiner to displace at least 20 percent of their existing feedstock with waste-based feedstocks. Participants in the CEPIP must achieve either of these goals according to a set timeline of milestones. The first milestone, not yet reached by any of the participants, requires the biorefiner to submit a draft plant for compliance with either of the BOEGs within six months of participation. In the first quarter of 2011, two of the five eligible CEPIP facilities are producing ethanol. It is expected that two more facilities could be operational in 2011.

The objectives of the CEPIP reflect the Energy Commission's broader objectives for alternative fuels. These include the production of an in-state alternative fuel that is widely used to meet state gasoline oxygenate content requirements. California consumed more than 1.4 billion gallons of ethanol in 2010. However, before CEPIP, more than 95 percent of this volume was imported from outside the state. The reopening of in-state biorefiners also has important job benefits, as each facility has been able to rehire dozens of workers that had been laid-off. In-state biorefiners also ensures a technology and facility base for California to expand into next-generation biofuels. Finally, the continued operation of these plants protects millions of dollars in existing private investment into California alternative fuels production, and gives participants an opportunity to leverage additional private investment in their facilities.

During the administration of the CEPIP, market conditions have becoming increasingly unfavorable for ethanol production, particularly within California. This is due in part to near-record commodity costs for corn. Given uncertain market conditions and future price projections, it is unclear whether a modest state price support program can offset the impacts of this unprecedented change in the ethanol fuel market. As a result, the Energy Commission will reevaluate the future of the CEPIP and study the benefits from its proposed $6 million investments before making a recommendation on funding.

Upstream Fuel Infrastructure

Over 80 percent of the nation's ethanol production is located in six Midwestern states and must be shipped to distribution terminals in other regions via truck, barge, or rail, transport modes which are more expensive than pipelines. California currently produces less than five percent of the ethanol it consumes, and will continue to rely heavily on imports even if this percentage increases. Ethanol is currently imported into California by unit train volumes moving from the Midwest to terminals in southern and northern California before being redistributed by truck.

In the near term, most of the projected increase in shipments of ethanol to terminals will be handled by tanker truck and rail tank car as opposed to pipelines. Except for a few proprietary pipelines, the common carriers generally do not ship ethanol in their systems. The increased risk of corrosion and potential for water contamination associated with ethanol are key factors limiting its transport via pipeline. Investment funding for distribution improvements is small. An existing infrastructure moves ethanol from production sites to service stations, and that process is not expected to materially change over the next 10-20 years. However, as ethanol demand grows due to RFS2 and LCFS requirements, the scope of the distribution system will need to expand. For the U.S. overall, new sources of ethanol from cellulosic plants will be producing ethanol from sites outside the traditional Midwest, requiring more truck, rail and barge movements to markets.

Local Fuel Infrastructure

Assuming a 10 percent ethanol blend wall, E85 sales in California are forecast to rise from 1.1 million gallons in 2010 to 1,725 million gallons in 2020 and 2,262 million gallons by 2030 under the Low Demand Case for gasoline.[254] Based on this previous analysis, the Energy Commission has forecast that the retail presence of E85 dispensers will need to dramatically expand if the state is to meet its fair share of RFS2 compliance. Depending on the average quantity of fuel sold by a typical E85 dispenser, California could require between 4,400 and 30,900 E85 dispensers by 2022. To put that estimated number of new dispensers into perspective, there were a total of approximately 42,050 retail dispensers in California during summer of 2008 for all fuel types.[255]

As of February 2011, 57 retail stations in California offered E85.[256] To date, the Energy Commission has funded two projects for 85 new E85 fueling stations using $5 million of funds from the Program. The project partners will provide $14.1 million and the DOE will contribute an additional $6.9 million.

A review of National Renewable Energy Laboratory's (NREL) FFV density map indicates that the highest density of FFVs is observed in major population centers including San Francisco, Los Angeles, San Diego and Sacramento. However, there are only a handful of E85 fueling

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254 Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report, California Energy Commission, Final Staff Report, report number CEC-600-2010-002-SF, May 2010.
255 Gordon Schremp and Nicholas Janusch, 2009. *Fuel Delivery Temperature Study*, California Energy Commission. CEC-600-2009-002-CMF.
256 U.S. DOE, "E85 Fueling Stations in California," http://www.afdc.energy.gov/afdc/progs/ind_state.php/CA/E85

stations in the Los Angeles basin. A pending survey of automakers will further clarify the regional needs for E85 fueling stations.

The primary barrier to establishing new E85 dispensers is the upfront cost. E85 retail infrastructure is expensive. Costs for installing a new UST, dispenser, and appurtenances range between $50,000 and $200,000.[257] Statewide, the E85 retail infrastructure investment costs could be as low as $192 million to upwards of $4.7 billion between 2009 and 2020. Between 2009 and 2030 the E85 dispenser infrastructure costs could range from $251 million to $6.1 billion. Most conventional service stations are no longer owned by oil companies, and the investment needed to accomplish the conversion to E85 must be borne by the independent dealer. Moreover, most conventional service stations generate profits from convenience store sales and service or repair business, while usually breaking even on fuel sales. Investors have the challenge of recovering significant investment cost while marketing an initially lower volume product.

The most significant factors in fuels sales are location and price. Locating E85 stations at high volume stations on busy commuter routes will be an important factor in achieving the required volumes. Another factor in siting E85 stations is the size of many existing service stations, which occupy small parcels of land that cannot readily accommodate an additional tank. The service station owner may be reluctant to dedicate an existing tank to E85 due to initial low penetration and volume sales of E85. In the absence of external funding sources, retail availability of E85 would solely rely on retail site owners voluntarily choosing to invest in E85 dispensing equipment.

Permitting for the development of stations must be done through the local Authority Having Jurisdiction (AHJ) – usually the local fire marshal. According to the State of California Supervising Deputy State Fire Marshal, there are local fire marshals who do not allow the permitting of the construction of E85 distribution stations within their jurisdiction.[258] Other AHJs consider E85 as a fuel equivalent to gasoline and are determining E85 distribution equipment as having natural equivalency.

In June 2010, UL certified two fuel dispensing systems for E85, including dispenser, hose, nozzle, swivel, breakaway, and shear valves. Because UL policy stipulates its listings apply only to those particular units that were manufactured after the date of certification, current retailers who sell E85 may need to purchase all new equipment. In addition, those retailers may need to

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257 National Association of Convenience Stores (NACS) and the Society of Independent Gasoline Marketers of America (SIGMA), Letter to Congress, March 27, 2006, http://www.sigma.org/pdf/E85-Mandates.pdf. According to the National Commission on Energy Policy's (NCEP) recent report, replacing an entire system can be expected to cost substantially more than $150,000 per facility depending upon the market. *Task Force on Biofuels Infrastructure*, NCEP, May 2009, Appendix B, page 53; available from http://www.energycommission.org/ht/a/GetDocumentAction/i/10232. Additional cost estimates for both new and retrofit scenarios are provided in the following brief paper: *Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search,* National Renewable Energy Laboratory, Publication NREL/FS-540-42390, March 2008, http://www.afdc.energy.gov/afdc/pdfs/42390.pdf

258 ICF conducted interviews with the State of California Supervising Deputy State Fire Marshal to develop a clearer understanding of the safety and permitting issues associated with E85 stations.

ensure that their underground equipment is also listed as compatible or replace the entire system, an expensive undertaking.

Given the anticipated demand growth for E85 and the associated retail station infrastructure needs discussed above, the Energy Commission intends to allocate $5 million for the further expansion of E85 fueling infrastructure. This amount of funding could provide 50-75 stations, depending on capital cost. This funding will be guided by results of a survey of automakers, which will provide information on the numbers and locations of FFV deployments.

Vehicles

Engine modifications are needed to accommodate E85, while retaining capability to operate on gasoline or any blend containing up to 85 percent ethanol. Modification costs, however, are sufficiently low that U.S. automakers have produced FFVs since 1993, primarily to take advantage of the credit allowed toward meeting corporate average fuel economy (CAFE) standards, as provided by the Alternative Motor Fuels Act of 1988. According to the Office of Energy Efficiency and Renewable Energy, there were about 8.4 million E85 FFVs on the road in the U.S. in 2009, with more than 400,000 of these in California. Due to the limited availability of E85 and the cost relative to gasoline, the majority of FFVs never use this fuel.

All gasoline vehicles can now use E10 blends safely, and EPA has determined that newer (post 2000) vehicles can use E15 safely (EPA-420-F-11-003). As older vehicles are retired, most of the fleet will be E15 capable by 2015. However, several barriers would need to be overcome if E15 use were to become a reality in California. California has its own reformulated gasoline regulations that are based on vehicle testing of gasoline with ethanol no greater than 10 percent. New testing of vehicles, assuming no deleterious emission impacts, would take time – at least three years to complete. In addition, no vehicle manufacturer allows ethanol concentrations in excess of 10 percent to be used without violating the vehicle warranty. Finally, service station owners have no liability protections against misfueling damage claims for people that use E15 in vehicles older than 2001 MY.

In contrast, E85 can be used only in vehicles designated as an FFV. Future emission standards for California will make certification of FFV models more difficult in California. At the Federal level, new fuel economy regulations phase out the fuel economy credits available to manufacturers for producing FFV models by 2020.[259]

The FFVs currently account for 1.5 percent of California light duty vehicles, or approximately 400,000 vehicles.[260] All E85 use is in the light duty vehicle category. By 2020, projections based on DMV vehicle registration data indicate upwards of 800,000 FFVs for both light- and medium- duty applications.[261]

In order to make a gasoline vehicle ethanol-capable, manufacturers install a computerized optical sensor or other technology that detects how much ethanol is in the fuel mixture. Because

259 ICF International, "Technical Analysis for the Alternative & Renewable Fuel & Vehicle Technology Program - Task 2 –Evaluate Alternative and Renewable Fuel Infrastructure and Distribution Development for E85," draft unpublished report, November 22, 2010.

260 DMV

261 Energy Commission staff estimate, based on DMV data.

ethanol is more corrosive than gasoline and has less energy content, manufacturers need to use modified materials and larger sizes for the gas line, gas tank, pumps, and injectors.

E85 has about 30 percent less energy per gallon so the fuel efficiency of a FFV running on E85 will be about 30 percent lower on a volumetric basis. As a result the vehicle range will be proportionally reduced since OEMs do not typically specify larger fuel tanks for FFVs. This means that E85 prices should be reduced a comparable percentage to be fairly priced at gasoline-gallon equivalent prices.

In 2006, Ford, DaimlerChrysler, and General Motors indicated they would produce 2 million FFV vehicles by 2010. In May of 2010, Ford announced they would fulfill their projection by the end of the year. Ford has also announced that FFV certified engines would be available on 50 percent of nameplates by Model Year (MY) 2013, including new small engines such as in the Focus. GM made a commitment that more than 50 percent of its production by MY2013 will be FFV. DaimlerChrysler made this same pledge.[262]

The high octane rating of E85 is a significant driver for research into vehicle technologies that optimize engine technologies that capitalize on this physical property of the fuel. Most researchers focus on increased compression ratio engines operating with natural, or more frequently, boosted aspiration. For example, Ricardo has demonstrated an Ethanol Boosted Direct Injection (EBDI) engine with extreme downsizing and estimated that a fuel economy improvement of up to 30 percent is possible on equal performance basis.[263]

Ford is supporting the development of a similar technological approach using ethanol boosting systems.[264] The proposed technology uses conventional gasoline fuel in higher compression ratio engines as long as a small quantity of E85 is available on board for high load conditions when engine knock is most likely to occur. Their research determined that a small, turbocharged, high-compression-ratio spark ignition engine can provide the same peak power as a naturally aspirated gasoline spark ignition engine but will be 20 to 30 percent more fuel efficient. As a reference, that level of fuel economy increase is provided by some of today's hybrid vehicles but at a substantial cost disadvantage.

Table 19: Ethanol Funding Allocation

Advanced Cellulosic Ethanol Production Plants	$7.5 Million
E85 Fueling Stations	$5 Million
Total	$12.5 Million

262 ICF International, "Technical Analysis for the Alternative & Renewable Fuel & Vehicle Technology Program - Task 2 –Evaluate Alternative and Renewable Fuel Infrastructure and Distribution Development for E85," draft unpublished report, November 22, 2010.
263 Ricardo Motors, "The Impact of Federal Requirements on Future Vehicle Technologies", Presentation at AVT Conference, October 30, 2009
264 Ethanol Boosting Systems, LLC, "Ethanol Turbo Boost for Gasoline Engines," http://www.ethanolboost.com/EBS_Overview.pdf

Diesel Substitutes

Diesel substitutes are defined as biomass-based diesel fuels including biodiesel and renewable diesel, as well as specific feedstock- and process-based diesels such as algae-based diesel, biomass-Fischer-Tropsch diesel, and diesel from thermal depolymerization of industrial and food processing waste. Of these fuels, only biodiesel is commercially available in California and renewable diesel now produced in Louisiana USA, and abroad in Rotterdam, Singapore and Finland.

Biodiesel refers to a non-petroleum-based diesel made from vegetable oils or animal fats using a process called transesterification. This is a simple process that blends bio-oils and a catalyst to make a biodiesel fuel, which is often blended with conventional petroleum-based diesel. In 2008, California used 58.7 million gallons of biodiesel.[265] Today, California has the potential to expand its biodiesel use to 200 million gallons within the industry-accepted blend of 5 percent biodiesel and 95 percent conventional diesel (also known as B5) without requiring modifications to vehicles and downstream infrastructure.

Renewable diesel can be made from a variety of feedstocks and is typically processed in a refining facility where the feedstocks are transformed into a diesel fuel through hydrocracking and hydrogenation. The refinery-based process produces a renewable diesel fuel that is chemically identical to diesel fuel, requiring no modifications for infrastructure or diesel engines.

Biomass Fischer-Tropsch diesel can be made from agriculture waste, green waste, food waste, or forest residue. Through a gasification process, the biomass is converted into diesel and naphtha. The final diesel product has superior fuel qualities and can be used in any blend level with conventional diesel fuel and infrastructure.

Biochemical processes for fuel production are being researched by several companies (such as Amrys, Solazyme, Jiangsu Yuehong Chemical Co., Ltd.). Biochemical processes vary considerably, and the final fuel product specifications are as varied as the processes and are in the beginning stages of development. Energy Commission staff will continue to monitor these promising technologies.

Algae-derived diesel is a research-phase effort that involves growing algae in ponds or in containers that either reacts with sunlight and CO_2 or is fed sugar to reproduce and create oils for later separation and use in any biomass-based diesel process. Algae is an especially attractive fuel source for diesel, gasoline, and aviation fuel, since the process does not require arable land and results in a fuel with up to an estimated 80 percent reduction in GHG emissions compared to petroleum-based diesel.[266] Additionally, algae-derived diesel may have a significant potential to replace conventional fuels due to its ability to produce up to 30 times more oil per unit of growth area than land plants.[267]

265 Energy Commission staff, based on data from the California Board of Equalization.

266 (S&T)2 Consultants, Inc., *The Addition of Algae and Jatropha Biodiesel to GHGenius*, September 30, 2009.

267 NREL, *Aquatic Species Project Report FY 1989-90*. January 1992.

Diesel substitutes could be significant contributors to reduce GHG emissions in California's transportation sector. Depending on the feedstock, biomass-based diesel fuels reduce GHG emissions 50 percent to 88 percent compared to conventional diesel fuel.[268] Additionally, the 58.7million gallons of biodiesel used in California in 2008 had the estimated emissions reductions (with the exception of nitrogen oxide [NOx], which increases) shown in Table 20.[269]

Table 20: 2008 Estimated Emission Reductions from 50 Million Gallons of Biodiesel Compared to Conventional Diesel

	Particulate Matter	Hydrocarbons	Carbon Monoxide	NOx	SO_2
Percentage Reductions	47	67	48	-10	100
Emission Reductions (lbs)	252,000	282,000	2,780,000	-775,000	221,000

Source: National Biodiesel Board

The ARB's Research Division is investigating biodiesel NOx impacts, and its staff released a draft biodiesel NOx mitigation plan. The staff draft biodiesel NOx mitigation plan relies on blending renewable diesel or a common cetane improver to render biodiesel's NOx emissions neutral, requiring no further mitigation. An ARB hearing and regulation on this is anticipated in October 2011.

Biodiesel is today's option, but it requires bulk storage and rack modifications to significantly expand beyond its current volume. Ultimately, biodiesel is expected to supply less than 10 percent of California's diesel demand due to feedstock supply limitations. In the mid-term, renewable diesel is envisioned to become a commercial product, will be comingled with petroleum diesel, flow through the existing pipelines and dispensed from petroleum storage and rack terminals. In the long term, renewable diesel can also use the separate and dedicated storage and blending facilities established for biodiesel.

It is expected that most renewable diesel would be produced at refineries on California's coast, and the fuel transported via pipeline throughout the state. Concurrently, most biodiesel is envisioned to be produced in the Central Valley or in more remote locations, and areas not served by the pipelines connected to major refineries.

The key obstacles for biodiesel are economic viability due to high feedstock costs and the lack of California bulk infrastructure. To become a more viable fuel option, California will need strategic deployment of blending and storage terminals to increase the availability of biodiesel and renewable diesel to customers. Additional progress will be needed to produce fuels from renewable feedstocks (including algae and the organic fraction of municipal waste sources) and purpose-grown crops, as well as to demonstrate the market viability of these sources. Resuming the federal subsidy of $1 per gallon may spur biodiesel's economic viability in the short term and by the federal RFS and the California LCFS in the long term. In addition, automakers and

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268 U.S. EPA, *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels*. EPA-420-F-10-006. February 2010. http://www.epa.gov/otaq/renewablefuels/420f10006.htm. Also based on ARB's LCFS look-up tables, available at http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf.
269 Based on an emissions calculator provided by the National Biodiesel Board at http://www.biodiesel.org/tools/calculator/default.aspx.

engine manufacturers will need to show widespread acceptance of higher biodiesel blend concentrations for use in all diesel vehicles. California has several compelling reasons to increase in-state production and use of biomass-based diesels:

- Significant emission reductions from lower carbon intensity.
- Along with biomethane, biomass-based diesel represents one of the most effective alternative fuels for reducing GHG emissions. It also provides a significant petroleum diesel gallon displacement, thereby diminishing California's dependence on petroleum.
- In-state biodiesel production plants are needed to ensure California's "fair share" biofuel use of 60 million gallons per year by 2022 as specified in the RFS of the EISA.[270]
- The LCFS identifies a major role for biofuels, such as biomass-based diesel, in achieving the 10 percent carbon intensity reduction target. Biofuels are projected to contribute 60 percent to 89 percent of the carbon intensity reductions.[271] Up to 30 new biorefineries could be needed in California to meet the LCFS carbon intensity reduction requirements for diesel fuel.[272]
- California has biomass waste streams from agricultural, municipal, and forest sectors available for the production of biofuels with low carbon intensity. Bioenergy specialty crops such as algae, jatropha, and canola can be grown on marginal land to produce biofuels using conventional conversion technologies.
- To meet the 2010 in-state production goal in California's BAP, the state needs to restart its largely idle in-state production capacity of 68 MGPY. In-state production increases California jobs and economic benefits and reduces GHG emissions by minimizing imported fuel transport costs and impacts. California needs to add 4-8 new facilities for a total of 115 million gallons of new capacity to meet the 2020 BAP goal.[273]

Biodiesel/Renewable Diesel Fuel Use and Vehicles

In 2010, 1.0 million on-road diesel vehicles were registered in California, consuming 2.6 billion gallons of diesel. Off-road diesel demand adds an additional one billion gallons. Heavy-duty and off-road vehicle applications use over 92 percent of all diesel fuels and therefore represent the key market for biomass-based diesel fuels.[274] Biodiesel has unique fuel properties that require a unique American Society for Testing and Materials (ASTM) D-6751 fuel specification.

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270 Staff estimates of future transportation fuels supply and demand forecasts for biodiesel use obligations under EISA used in the Transportation Energy Forecast for the *2009 Integrated Energy Policy Report (2009 IEPR).*

271 California Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard: Initial Statement of Reasons*, March 5, 2009, http://www.arb.ca.gov/regact/2009/lcfs09/lcfs09.htm.

272 Staff finds 1.4 billion gallons of soybean biofuel is needed at 68 g GHG/MJ by 2020. Assuming 50 million gallons per plant, 28 plants would be needed. Conversely, 8 yellow grease plants would be needed; however, there is not enough yellow grease in California to fuel 8 plants. Based on Energy Commission staff analysis done in support of the *2009 IEPR*.

273 This assumes 15-30 million gallons/year plant size respectively.

274 Energy Commission staff analysis.

It also has special handling, storage, and use requirements. This fuel poses challenges with vehicles and engine durability, fuel plugging, variable fuel quality, and cold weather properties.

Renewable diesel has less variable fuel properties than biodiesel and complies with ASTM D975 (petroleum diesel fuel) or ASTM D396 (home heating oil).[275] These characteristics are favored by engine manufacturers. Based on current ASTM specifications, renewable diesel fuels are not anticipated to require any vehicle modifications or preventative maintenance.

Today, the main barrier to expanded B20 use is the 20 cent to 40 cent per gallon higher price for B20 than standard diesel. Future renewable diesel fuels are expected to encounter the same higher price challenge as biodiesel because both use the same expensive feedstocks. Since 1992, most diesel fleets obligated to meet federal alternative fuel use requirements use B20 as the lowest-cost compliance option.[276] Most major medium- and heavy-duty diesel engine vehicle manufacturers accept blends of up to B20 in their vehicles, which are also accepted as an alternative compliance option for the federal alternative fuel vehicle purchase requirements.[277] Federal fleets required to use an alternative fuel in medium- and heavy-duty vehicles provided sufficient market opportunity for some manufacturers to build B20 compatible vehicles in limited models. These medium- and heavy-duty engines were not subject to the aggressive emission reductions required of light-duty vehicles since the 2004 model year, but the 2010 heavy-duty diesel engine standards will be as stringent as the 2004 light-duty standard.

All light-duty diesel cars and pickup trucks can use B5 blends without voiding manufacturers' warranties. However, new light-duty diesel vehicles are susceptible to biodiesel's engine-oil-dilution and have critical emission control needs. As a result, vehicle manufacturers are currently not recommending higher blends for use in new light-duty vehicles although some are conducting research that may enable future B20 acceptance. Since renewable diesel blends of up to 90 percent meet conventional diesel standards, light-duty diesel vehicle manufacturers are not likely to be as concerned with higher blends of renewable diesel as they are with higher blends of biodiesel.[278]

In November 2008, ASTM International adopted new biodiesel standards for B5, B20, and B100 blends to address the fuel quality problems identified in the last decade. The Energy Commission is funding additional work to develop and perform test methods for the development of national standards for biodiesel blends greater than 20 percent by volume.[279] Compliance with the recently established ASTM B5 standard would provide the opportunity to triple biodiesel use.

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275 National Biodiesel Board. *Biodiesel, Renewable Diesel & Co-Processed Diesel*. http://www.biodiesel.org/pdf_files/fuelfactsheets/Co-Processing%20One%20Pager.pdf.

276 The Energy Policy Act of 1992 regulations require that federal, state, and alternative fuel provider fleets build an inventory of alternative fuel vehicles.

277 National Biodiesel Board, "OEM Information / Standards and Warranties," http://www.biodiesel.org/resources/oems/default.shtm.

278 Renewable diesel engine testing finds that blends up to nearly 90 percent have the ability to meet ASTM 975 Standards, Preliminary Results from Neste and Conoco Phillips Testing, 2003-2007.

279 This task part of a $4 million agreement with Department of Food and Agriculture.

In 2008, 1.6 million gallons of biodiesel were sold at 39 retail stations within California. Of these 1.6 million gallons, 1 million gallons were sold as part of B20 blends, and 250,000 gallons were sold as B99 blends.[280] The majority of fuel was used by non-retail facilities such as commercial fleets, governmental entities, private card locks, and rental companies, most of which relied on B20 blends.

Funding for vehicle demonstrations is not recommended for biodiesel vehicles. The producers of some new biomass-based diesel fuels are requesting vehicle demonstration funds. These demonstrations will allow for pre-commercial identification and correction of any deleterious engine effects that might otherwise dissuade light-duty vehicle manufacturers. While the Energy Commission will continue to monitor this opportunity, it is not currently allocating any program funds for this purpose.

Fuel Production

California has 12 biodiesel plants with a combined annual production capacity of 76 million gallons. Due to the industry's inability to compete with petroleum-based diesel prices, these plants likely produced less than 25 million gallons in 2010. Six plants, representing one-third of the state's biodiesel production capacity, are idle due to their price disparity.[281] The BAP requires a minimum of 20 percent of biofuels to be produced within California by 2010 and 40 percent by 2020. With an estimated diesel demand of 5.25 billion gallons by 2020, a minimum of 200 million gallons of biomass-based diesel and other biofuels are needed, requiring an in-state plant expansion of up to 115 million gallon. The CARB LCFS program's 2020 goal is projected to require 0.7-1.0 billion gallons of diesel substitutes assuming 50-75 percent carbon reduction respectively – assuming 5.25 billion gallons of diesel demand in 2020.

Biodiesel plants use recycled cooking oil (yellow grease) as their lowest-cost and lowest GHG feedstock and use more expensive—and typically higher GHG—feedstocks such as soybean, palm, and a variety of plant and animal oils. To reach higher diesel substitute volumes, second generation feed sources and plants are necessary like biomass-based cellulose, waste, and algae. Second generation plants will need assistance as they move into pilot and pre-commercial scale plant sizes. Expansion of both first and second generation biofuel plants is needed to reach the 2020 goals. Building biofuel plants is one of the most effective and fastest ways to reach the goals of the BAP, and directly supports California's economy.

A federal $1 per gallon incentive for biodiesel production began in 2002 and expired on December 31, 2009, but was resumed in December 2010. The federal subsidy expiration significantly reduced biodiesel production nationwide and in California. The ARB's LCFS program has a gradual phase-in, and will not significantly impact the market demand for biodiesel for another year. Accordingly, fuel producers will have little motivation to invest in ensuring these plants' continued operation in the short-term. The LCFS should provide a 10-cent to 75-cent per gallon market price premium for biofuels providing 40 percent to 90 percent GHG reduction in a $20-$60/metric ton GHG market, respectively.

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280 Energy Commission, Petroleum Industry Information Reporting Act data.

281 Comments submitted by the California Biodiesel Alliance, Energy Commission Docket Number 09-ALT-1, February 16, 2009.

On November 12, 2009, U.S. DOE and the USDA announced $24 million in funding in Biomass Research and Development grants to produce biofuels. Of these funds, $1.6 million was awarded to a California firm. The ARB does not fund infrastructure, and California's regional air quality management district's have not awarded funds in this area. The Energy Commission awarded $2,845,744 for five diesel substitute projects using funds from the first investment plan. An additional $3.9 million solicitation is planned for FY 2010-2011 funds.

For FY 2011-2012 the Energy Commission is allocating $7.5 million, including possible loans and loan guarantees, to support new diesel substitute plants or plant expansions. California needs to expand current production to at least 700 million gallons to reach 2020 Bioenergy Action Plan goals and to support ARB LCFS objectives.

Fuel Terminal Storage and Blending

For California to reach the 2050 GHG emission reduction goals and other near-term goals, all biomass based diesel sources must have access to California's market. Biomass-based diesel use must, at a minimum, expand to half a billion gallons by 2015 and one billion gallons by 2030. Maximizing in-state and domestic supplies is the first priority but may not be sufficient to reach the goals if unfavorable market conditions persist.

Consequently, the continued growth of biomass-based diesel produced and used in California may depend on establishing bulk storage and terminal blending facilities for importing biofuels and feedstocks. California imports approximately 62 percent of its transportation fuels from domestic and foreign sources, and this amount continues to grow for petroleum and biofuels alike.[282] Biodiesel and renewable diesel will require bulk terminals to receive and store the large volumes of bio-oils required to competitively produce renewable diesel. ARB's LCFS carbon intensity and sustainability requirements will ensure that future imported renewable fuels are sustainably grown and provide lower carbon intensity.

Nearly all bulk receiving terminals are located with access to marine ports, railroads, and pipelines sufficient to move the fuel volumes into the 4 billion gallon per year diesel market. Adding biofuel capacity and modifying existing bulk terminals to accept biofuels are critical to biofuels' expanded future use.

Terminal blending racks are used to store bulk volumes of unblended fuels and dispense blended fuels for trucks to deliver to retail, fleets, and farm customers. California terminal racks are not modified to accept biodiesel fuels. Biodiesel terminal rack modifications can lead to a significant expansion of biofuel volumes due to the ease, lower-cost and time to load the fuels compared to today's method. In California, biodiesel fuels typically experience after-plant transport costs of 15 cents to 50 cents per gallon, compared to 9 to 12 cents for gasoline and diesel fuel.[283] These higher transportation costs should be eliminated with the establishment of appropriate rack terminal modifications to accept the biofuel.

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282 Schremp, Gordon, Aniss Bahreinian, Malachi Weng-Gutierrez. *Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report,* Draft Staff Report. California Energy Commission CEC-600-2009-012-SD.

283 Tellurium's comments made at the Energy Commission workshop November 2009.

Retail sales of low-level B5 biodiesel blends through existing retail facilities that require no modifications - referred to as drop-in fuels - are hampered by a lack of wholesale storage and distribution biodiesel facilities. Regionally located distribution terminals with B99 storage tanks are needed so that B5 blends can be loaded for distribution to local retail diesel and biodiesel stations.

The relatively poor or marginal blending economics for biodiesel means that the payback for the investment in a storage tank at a distribution terminal can be questionable for the operator of the facility. In addition, the independent jobbers who want to be able to sell B5 to retail normally do not own and operate distribution terminals, which means they have little control or say on whether or where a B99 storage tank is constructed. Strategically allocated funding from the Energy Commission provide an opportunity to substantially increase the distribution and end use of low level biodiesel blends in retail markets that are price sensitive.

Currently, financial institutions are not funding biodiesel infrastructure projects. Funds from sources such as the federal government, ARB, or local air quality districts have not been made available for biodiesel infrastructure investments. The Energy Commission's program funds alone are not sufficient. However, program funds used as a grant or loan guarantee may be able to leverage funds from other financial institutions to minimize the risk for companies to make improvements in advance of economic necessity.

For FY 2008-2010, the Energy Commission allocated $4 million for blending and storage terminal projects as part of a broader solicitation for alternative and renewable fuel infrastructure in November 2009. From this solicitation, approximately $3.86 million has been awarded as identified in Table 21.

Table 21: Previously Funded Diesel Substitute Infrastructure

Project Description	Award
Port of Stockton biodiesel fuel terminal	$1,999,379
Two biodiesel blending facilities	$1,790,000
Bulk biomass dispenser adjacent to San Jose pipeline terminal	$69,223
Total	$3,858,602

Source: California Energy Commission

For FY 2011-2012 the Energy Commission is allocating $4 million, including possible loans and loan guarantees, to expand the number of terminal blending facilities, and fleets storage and dispensing equipment capable of handling biodiesel fuels. California has more than 100 rack-terminals requiring modifications to dispense biomass-based diesel. Based on FY 2008-2010 funded projects, infrastructure modification costs are estimated to be $500,000 to $3.0 million per site. Making these modifications would reduce retail prices of biomass-based diesels and increase biodiesel throughput. An allocation of $4 million dollars could fund one fifth of the terminal modifications at 20 percent of the total conversion cost, assuming $1 million/terminal total conversion cost.

Table 22: Diesel Substitutes Funding Allocation

Expand Diesel Substitute Production (conventional and advanced	$7.5 Million

generation plants)	
Bulk Terminal Storage, Blending Facilities and Fleet Dispenser equipment	$4 Million
Total	$11.5 Million

Source: California Energy Commission

Biomethane

Biomethane, or renewable natural gas, is most commonly sourced from the anaerobic digestion or gasification of organic matter. These processes result in a biogas, which can then be cleaned up to biomethane with the removal of impurities such as carbon dioxide, hydrogen, sulfide, and water. Biomethane can be used as an energy source in transportation, power generation, and combined heat and power application, including:

- Direct use as a fuel and heat source for boilers or industrial heat.
- Injection into utility-operated natural gas pipeline systems for use by residential,
- Commercial, and industrial customers; and for use in powering natural gas electricity generating stations.
- Blended or enhanced with hydrogen, further extending its GHG benefits, or used as a
- Feedstock in hydrogen production.
- Refined into gasoline and diesel via gas-to-liquid technologies.
- Compressed into CNG or liquefied into LNG for use in transportation applications.

In the transportation sector, biomethane is a highly desirable alternative to fossil fuels as it has low Carbon Intensity (CI) values as determined by ARB on a well-to-wheels basis. Compared to traditional fuels such as gasoline, diesel, and fossil-based natural gas, biomethane can reduce emissions by up to as much as 87 percent.[284] These reductions can be even higher if additional technologies, such as a carbon sequestration process, are used. As determined by the LCFS, biomethane is the lowest carbon intensity alternative fuel readily available in California.

Biomethane can be generated from a variety of biomass sources. However, the Energy Commission favors the use of waste stream feedstocks for the transportation sector because of the high emission reduction potential and other environmental and health benefits realized on a wells-to-wheels basis with these feedstocks. California's waste streams have a gross production potential of 124 billion cubic feet (BCF) per year and a technical potential of 23 BCF per year, equivalent to 174 million DGE[285], representing approximately 7 percent of the state's on-road

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284 Detailed California-Modified GREET Pathway for Compressed Natural Gas (CNG) from Landfill Gas, February 2009. Detailed California-Modified GREET Pathway for Ultra Low Sulfur Diesel (ULSD) from Average Crude Refined in California, February 2009. 87 percent reduction based on landfill gas to CNG pathway compared to diesel baseline.

285 Ken Krich, "Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California." Technical potential is based on physical system constraints including but not limited to agronomic and ecological requirements, terrain limitation and inefficiencies in collection and handling. DGE calculated based on technical potential using conversion of 106 BCF = 800 MDGE

diesel fuel usage. Some of the most likely feedstock sources include diverted organic material from post-recycled municipal solid waste streams, animal manures, woody biomass from forest fuels management activities, agricultural residues, food waste, and waste water treatment waste.

MSW one of the largest waste streams available in California and is a prime feedstock for conversion to biomethane as it will not only be using a waste product for energy production, but will also be diverting waste from entering landfills, thus extending the life of landfills. Approximately 39 million tons of MSW are landfilled annually, and about 22 percent of that is suitable for anaerobic digestion. Two of CalRecycle's Strategic Directives further support the diversion of organic matter from the landfills, requiring 50 percent reduction of organics in the waste stream by 2020 and encouraging the development of alternative energy and biofuels.[286] MSW is composed of 57 percent biomass which can be separated using various methods, with the remainder being plastics, textiles, and non-organics.[287] When diverted from landfills, the organic fraction of MSW has ten times greater energy production potential on a per ton basis compared to landfilled waste.[288] Another benefit to MSW as a feedstock source is that an established collection system is already in place, and the waste is already transported to centralized locations.

Although production potential for biomethane is significant, currently there are a limited number of biomethane or biogas projects operational in California. To date, the AB118 Program has funded nine biomethane projects with over $33 million. These projects, spread throughout the state, are in various phases ranging from feasibility to commercialization and use a variety of feedstocks including waste water treatment sludge, food waste, animal manures, landfill gas, woody biomass residues, and post-sorted MSW. Once fully commercialized, these projects are expected to displace a combined total of over 6.5 million DGE.

As more biomethane projects come online, it will be important that there is access to natural gas pipelines. When connecting to the natural gas pipelines interconnection can be a financial burden. Gas quality testing and certification is an expensive process with no certainty over who should pay for it–biogas developers, natural gas utilities, or other third parties. For biomethane from new feedstocks such as agricultural residues and food waste to be able to enter the natural gas pipeline, extensive gas quality testing must be performed. This testing can be very costly.[289]

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286 CalRecycle's strategic directive 6.1 identifies a reduction of the amount of organics in the waste stream by 50 percent by 2020 and strategic directive 9.2 is to encourage the development of alternative energy and biofuels. http://www.calrecycle.ca.gov/AboutUs/StrategicPlan/

287 Rob Williams, *Biofuels from Municipal Wastes Background Discussion Paper*, March 28, 2007

288 One ton of organic waste landfilled has a 65kW potential while one ton of MSW has a 550 kW potential. Energy Commission meeting with CalRecycle, October 28, 2010

289 Brennan, Ken. "Re: PG&E Gas Quality Testing Cost Estimate." Private communication to Energy Commission staff. November 18, 2009. Initial research for new biomass feedstocks will cost between $340,000 and $500,000 as a one-time expense, and then each project will require ongoing gas sampling which is estimated at $20,000 per month. These numbers are subject to increase with more complex feedstocks.

Without access to the natural gas pipeline, a number of producers will have to determine other methods for moving their product into the market.

In order for the biomethane for transportation industry to successfully develop, California will have to ensure supportive government policies and additional financial incentives. Because this is a relatively new industry, additional financial incentives are needed to help offset high capital costs. In light of the $33 million already allocated to biomethane projects, funding is still a substantial need. Consequently the Energy Commission is allocating $8 million for FY 2011-2012 to help further establish the biomethane for transportation industry. The allocation will focus on projects that use a variety of pre-landfilled waste materials as a feedstock and will provide financial assistance to projects that require gas quality testing on new feedstocks entering the natural gas pipeline.

Table 23: Biomethane Funding Allocation

Biomethane Production and Support	$8 Million
Total	$8 Million

Source: California Energy Commission

Medium- and Heavy-Duty Vehicles

Medium- and heavy-duty vehicles, consisting of vehicles with a gross vehicle weight rating (GVWR) of more than 10,000 pounds, represent a significant component of California's transportation sector. These vehicles account for approximately 16 percent of the state's petroleum consumption and 16 percent of GHG emissions within the transportation sector. Table 24 below summarizes the number of vehicles and petroleum demand in each GVWR class.

Table 24: Medium- and Heavy-Duty Vehicles and Petroleum Use

Truck Classification	Vehicles	Petroleum Use (Gallons/Year)	Average Petroleum Use per Vehicle (Gallons/Year)
GVWR 3 TRUCK	283,939	341,673,885	1,203
GVWR 4 TRUCK	154,235	230,804,674	1,496
GVWR 5 TRUCK	65,034	123,506,209	1,899
GVWR 6 TRUCK	182,872	410,903,496	2,247
GVWR 7 TRUCK	83,210	496,086,082	5,962
GVWR 8 TRUCK	147,186	986,248,158	6,701
Total	916,476	2,767,053,537	

Source: California Energy Commission, *Total Fuels Use Analysis*, 2009 DMV Data.

As shown, each of these vehicles utilizes a significant amount of petroleum fuel, particularly when compared to a light-duty vehicle. For comparison, a light-duty truck that averages 20 miles per gallon and 12,000 miles per year uses 600 gallons per year, while a passenger sedan that averages 30 miles per gallon and 12,000 miles per year uses 400 gallons per year. On a per-vehicle basis, then, medium- and heavy-duty vehicles represent an excellent opportunity to expand alternative fuel use, reduce petroleum consumption, and lower GHG emissions, as outlined in Table 25.

Table 25: Petroleum and GHG Reductions

Vehicle Type	Incremental Cost of an Alternative Fuel Vehicle	Petroleum Reduction (Gallons per Year)	GHG Emission Reduction (metric tons $CO2_e$/year)[290]
GVWR 8 Diesel Truck	$40,000 (for CNG)	6,701 (based on historic average)	12.0
Light-duty Sedan (30 miles per gallon; 12,000 miles per year)	$10,000 (for BEV)	400	3.2

Source: California Energy Commission staff estimates; Total Fuel Use Analysis for 2009

Medium- and heavy-duty vehicles serve a variety of purposes in California's economy, from student and public transportation to urban delivery to long-haul goods movement. This means that any attempt to encourage petroleum and GHG emission reductions must consider the unique applications of a particular vehicle. Using registration data from the Department of Motor Vehicles, the Energy Commission tracks the populations of nearly 40 medium- and heavy-duty vehicle vocations. Using this data, as well as fuel sales data from the Board of Equalization, the Energy Commission can estimate the annual petroleum demand for various vocations. This historical fuel use information, when combined with interviews from fleet managers, alternative fuel vehicle suppliers, and infrastructure providers, begins to form a foundation for the Energy Commission to identify and implement approaches for reducing petroleum and GHG emissions.

Natural Gas and Propane Vehicles

Natural gas and propane are again becoming popular alternative fuels for medium- and heavy-duty vehicles in California. In particular, the number of natural gas vehicles increased from less than 2,000 vehicles in 2000 to more than 12,500 vehicles in 2009; an increase of 10,500 vehicles over a period of nine years. The number of CNG and propane vehicles as of 2009, as well as their estimated petroleum displacement, is shown in Table 26. These numbers will further increase as a result of the Energy Commission's funding of two natural gas deployment projects (discussed below). Anticipated vehicle buy-down incentives for natural gas and propane, also funded by the Energy Commission, will further drive this market, incentivizing the purchase of an estimated 715 medium and heavy-duty gaseous fuel vehicles. [291]

290 Assumes heavy-duty natural gas vehicles have a 15 percent GHG benefit, and light-duty BEVs have 72 percent GHG benefit per the Energy Commission Full Fuel Cycle Assessment: Wells-to-Wheels Energy Inputs, Emissions, and Water Impacts, Analysis 8/1/2007 Consultant Report.
291 Energy Commission staff analysis, January 2011.

Table 26: Propane and Natural Gas Vehicles and Petroleum Displacement

Truck Classification	CNG		Propane	
	Vehicles	Petroleum Displaced (Gallons/Year)	Vehicles	Petroleum Displaced (Gallons/Year)
GVWR 3 TRUCK	316	404,542	196	313,648
GVWR 4 TRUCK	567	896,664	232	458,611
GVWR 5 TRUCK	89	151,436	64	136,122
GVWR 6 TRUCK	7,617	35,925,646	1,142	3,366,408
GVWR 7 TRUCK	267	1,121,571	325	1,706,510
GVWR 8 TRUCK	2,436	11,489,415	39	229,930
Total	11,292	49,989,274	1,998	6,211,229

Source: Department of Motor Vehicles, Board of Equalization

While these vehicle numbers are low compared to the overall market, they may not wholly reflect the direction of the transportation industry in recent or future years. Recent conversations with manufacturers of medium and heavy-duty vehicles and engines have shown a renewed interest in both natural gas and propane. Major vehicle manufacturers are or will be offering natural gas and propane options in their class 1 through 8 (<6,000 through >60,000 GVW) vehicles. While product offerings are small, they are finding acceptance in many niche markets such as refuse haulers, drayage trucks, and transit buses. U.S. corporations and fleets are seeing alternative fuels as a way to reduce GHG emissions and encourage wider use and production of efficient vehicles and domestic petroleum alternatives.

School bus and other transit bus vehicles represent a significant opportunity for natural gas and propane, and school districts have already shown an interest in these fuels. In particular, school buses may be more cost-effectively served with propane's lower incremental cost given school buses significantly lower annual fuel demand. Sales of the Bluebird school bus continue to increase, and school districts across California are expressing increased interest in propane school buses.

Since the 1990s, transit buses within the South Coast Air Basin have favored the use of natural gas to meet air quality standards, and, statewide, all transit buses receive significant Federal Transit Agency support to cover a high percentage of the upfront vehicle cost. Public transit also encourages reduction of vehicle miles traveled, which in turn reduces GHG emissions and petroleum use. Today, transit bus purchases represent nearly 600 vehicles /year, which is roughly half of all heavy duty natural gas vehicle sales. Given existing funding commitments, alternative fuel requirements for transit vehicles, and comparatively low petroleum demand by buses, the Energy Commission does not intend to supplement existing funding for transit vehicles. However, the Energy Commission plans to support workforce development and training efforts for transit to ensure that well-trained service and maintenance employees are available to support the deployment of these vehicles and keep them in service.

While light-duty passenger vehicles can be retrofitted to use propane, retrofits and upfits are more common for medium-duty vehicles used in fleets. Propane is viewed as an economical upfit option for delivery trucks, shuttle buses, and school buses. Propane vehicles are an especially viable option for more rural communities looking to use an alternative fuel for their vehicles or for an entire fleet because of its availability. The incremental cost for medium-duty and heavy-duty propane vehicle upfits depends on the application for which the system is being used. Systems in the $7,500 price range are typically for applications that include lighter trucks, while the incremental costs for shuttle and school buses are around $20,000. Companies and government fleets have already begun to express interest in and place orders for various medium and heavy-duty propane vehicles, including: Time Warner, Primetime, Supershuttle, City of Santa Monica, City of Riverside, and Marquez.

In order to support the development and deployment of advanced medium- and heavy-duty natural gas vehicles and infrastructure, the Energy Commission has already committed funding for the following projects using funding from the first investment plan:

- Gas Technology Institute (GTI) and Cummins Westport was awarded $1,777,364 to develop an advanced ISX11.9 G natural gas engine which will be a low-emission, high efficiency engine designed for the Class 8 market. Swift Transportation will demonstrate one engine in a highway tractor for 12 months to accumulate approximately 2000 miles per month while hauling loads up to 80,000 pounds gross vehicle weight. This engine will fill an important market gap where there is currently not a natural gas engine option available.
- South Coast Air Quality Management District (SCAQMD) was awarded $5,142,000 to offset the incremental cost of 120 commercially available new 2009 or 2010 model Class 8 Freightliner M2-112, Peterbilt, Kenworth, or other liquefied natural gas (LNG) drayage trucks. SCAQMD is partnering with the Ports of Long Beach and Los Angeles, which together are America's largest port complex. These ports together are the single largest fixed source of air pollution in the South Coast Air Basin. Each LNG drayage truck displaces approximately 10,000 gallons of diesel fuel each year.
- The San Bernardino Association of Governments (SANDBAG) was awarded $9,308,000 to purchase and deploy 202 heavy-duty natural gas trucks. SANDBAG has partnered on this project with Ryder Truck Transport Services, Inc. to purchase and deploy these trucks. The Department of Energy's American Recovery and Reinvestment Act funds will provide $9,950,708 for the construction of two liquefied natural gas refueling stations and truck purchases.

With funds from the second investment plan, the Energy Commission is also preparing to release a program opportunity notice for buy-down incentives for specific classes of natural gas and propane fueled vehicles. Incentives will be provided at varying levels depending on the class of vehicle. The incentives are intended to reduce the high initial capital cost of natural gas and propane vehicles to assist public and private fleets and individual consumers in making the decision to purchase and utilize vehicles powered by non-petroleum, lower-carbon, alternative and renewable fuels. The funding available for this solicitation is $14.04 million, and is estimated to cover incentives for approximately 1,800 natural gas and propane vehicles, with an estimated 715 being medium-duty or heavy-duty vehicles.

Based on historic vehicle and fuel data available to the Energy Commission, as well as the current market descriptions provided by vehicle suppliers and customers, the Energy Commission is well-positioned to identify effective opportunities for promoting petroleum and GHG emission reductions in medium- and heavy-duty vehicles. Towards this end, the Energy Commission will allocate $14.75 million in FY 2011-2012 for further purchase incentives to support the deployment of new, medium-duty or heavy-duty gaseous fuel vehicles; $3 million for propane vehicles and $11.75 million for natural gas vehicles. Using the same ratio from the previously discussed incentives, this level of funding should leverage approximately 375 to 750 additional medium-duty and heavy-duty natural gas and propane vehicles.

Advanced Vehicle Technologies

In addition to gaseous alternative fuels, several MD/HD vehicle suppliers have begun incorporating a variety of advanced vehicle technologies and other alternative fuels into their offerings, ranging from natural gas hybrid-electric vehicles to hydrogen fuel cell buses. In each of these cases, the qualities of the alternative fuel or advanced technology are being carefully matched to the duty cycles of the customer’s vehicle. For this reason, the use of alternative fuels or advanced technology may be limited to certain niche market applications where the payback period is most attractive. As the technologies evolve and if associated costs fall, the opportunity for broader deployment of these technologies will arrive, allowing them to expand into new applications.

The Energy Commission, through the PIER program, funded the CalStart CalHEAT (Hybrid, Efficient, Advanced Technologies) project for $3 million, establishing a center for research, development, demonstration and commercialization of advanced, efficient truck technologies and systems. Through this project, a roadmap will be developed, with industry input, to commercialize advanced technologies for medium-and heavy-duty vehicles by 2020. The project also includes vehicle demonstrations for parcel delivery trucks and Class 8 trucks.

Hybrid-electric and hydraulic technologies on medium and heavy duty vehicles can potentially reduce GHG emissions 60 percent on a full fuel-cycle basis compared to conventional diesel vehicles. Hybrid electric trucks use the engine to recharge the batteries, which assists the engine and auxiliary functions. Hydraulic-hybrids use a hydraulic pump and motor to capture regenerative braking and offer a power boost to the engine and auxiliary functions. Refuse trucks, drayage trucks, package delivery vans, utility trucks, transit and school buses, and harbor craft are the most practical applications for this technology, due to their unique duty cycles.

The Energy Commission has funded a number of hydraulic-hybrid demonstration projects in order to advance the state of the technology and match fleets and key niche markets with the appropriate vehicles. Examples of Program awards made for hydraulic hybrid vehicle demonstrations include:

- Coca Cola Enterprise, Inc. was awarded $750,000 to design, develop, and deploy four hydraulic hybrid Class 6 Coca Cola delivery trucks. These trucks may provide 40 percent better fuel economy over the conventional delivery trucks. Coca Cola Enterprises has the largest fleet of hybrid trucks currently deployed with 335 units in fleet operations as of January 1, 2010. Coca Cola Enterprise and the South Coast Air Quality Management District are providing matching funding totaling $1.25 million.

- Kenworth Truck Company and its partners were awarded $1,458,735 and will demonstrate one truck with an advanced class 8 hybrid electric system and an intercooled recuperated 350 kW microturbine. The ICR microturbine will be run on natural gas for this demonstration because of its low GHG potential, low cost, and distribution infrastructure. However, the microturbine will be capable of using any fuel including ethanol, LNG, hydrogen, and biodiesel. The system will initially be designed for class 8, but can be readily scaled to fit all class 6, 7, and 8 vehicles over a wide range of operation.

Additionally, the ARB funds the Hybrid Voucher Incentive Program (HVIP), which provides vouchers up to $40,000 for the purchase of eligible new hybrid trucks and buses. The ARB has selected CALSTART to administer the HVIP; however, the ARB maintains responsibility for designing and guiding the program. Unlike the Energy Commission's advanced vehicle technology demonstration projects, the HVIP provides incremental funding for vehicle deployment. Funding is provided on a first-come basis. The ARB's AQIP Funding Plan for FY 2010-11 allocated $19 million for this program; the funding level for FY 2011-2012 is still under development, but is still expected to remain a large AQIP investment.[292]

Battery electric and battery electric hybrid vehicles have also shown promise for certain applications. The following projects were funded under the same solicitation:

- ISE was awarded $888,595 to produce a battery-electric 45-foot transit bus for the Los Angeles Metropolitan Transportation Authority (LAMTA) Battery Electric Bus Program. ISE will install their electric drive system and lithium ion batteries in place of the engine and fuel storage tank. This is the first battery based technology to meet the "40 feet and greater" transit bus requirements. This size class represents two thirds of the transit bus market. If this demonstration is successful, the LAMTA is expected to purchase 30 to 40 buses per year on average.
- Motiv Power Systems, Inc. (Motiv), Bauer Worldwide Transportation, Inc. (Bauer), and Seeo, Inc. (Seeo) were awarded $1,345,552 to integrate Motiv's customizable electric-drive Power Control System into a prototype class 4 vehicle to demonstrate the viability and benefits of the system's 100-mile all-electric range. Motiv will install its system on a new shuttle bus chassis as a test platform to illustrate the large-scale applicability of the technology. This shuttle will operate along routes at campuses of Bauer's client companies, including Google, Cisco, Facebook, and Yahoo. Upon successful completion of the proposed project, Bauer will employ the vehicle technology in a large-scale roll-out of Motiv's electric-drive vehicle platform, which can be configured with different

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292 ARB, "AB 118: Air Quality Improvement Program (AQIP)," January 11, 2011, http://www.arb.ca.gov/msprog/aqip/meetings/fy%202010-11/fp11_12_presentation_011111.pdf

battery packs and with or without generators on board to meet the specific needs of medium- and heavy-duty vehicle fleets.

- Terex, in collaboration with Pacific Gas & Electric (PG&E) and CalStart, was awarded $494,678 to demonstrate the economic and environmental viability of its innovative new Hypower Hybrid system retrofitting 12 medium and heavy-duty PG&E utility service vehicles. The Hypower Hybrid uses stored energy from the system's rechargeable batteries to provide power for aerial boom operation, cabin heating and air conditioning, and worksite lighting. This will virtually eliminate the need for chassis engine idling during these types of operation which typically exceed more than 4 hours per day for the average utility service vehicle.
- Electric Vehicles International (EVI) is awarded $1,153,053 to design, develop, and deploy a range-extended electric vehicle powertrain for medium-duty truck applications. EVI proposes to build 10 Range-extended LNG medium-duty pickup trucks. The applicant proposes to use Valence lithium-phosphate batteries for a 100-115 mile range. EVI will integrate the new powertrain into an industry standard pickup truck and will deploy prototypes for onsite testing with partners.

Opportunities for hydrogen and fuel cell use in medium- and heavy-duty applications are also on the horizon. California has pursued development and deployment of alternative-fueled and hydrogen fuel cell transit buses through regulations and incentives for more than 10 years. Hydrogen fuel cell buses can reduce GHG emissions from 26 percent to 86 percent compared to conventional diesel buses, depending on the method of hydrogen production.[293,294] Fuel cell transit buses also almost double the fuel mileage (on a diesel gallon equivalent basis compared to a conventional diesel transit bus) and reduce particulate matter and air toxics associated with diesel.

Since 2004, the ARB has directed its staff to develop fuel cell bus (FCB) demonstration programs in the Bay Area and in Southern California. The HyRoad Program, led by AC Transit in Oakland/Emeryville, will roll out 12 hydrogen FCBs by April 2011 (five buses have been delivered). In addition, the ARB co-funded two FCBs with SunLine Transit in Twentynine Palms. Proterra, a Colorado-based vehicle manufacturer, has produced a battery-assisted hydrogen hybrid transit bus. One such bus is located at the Burbank city yard in Southern California but it has not entered regular transit service due to the lack of sufficient fuel supply at the Burbank hydrogen fueling station.

Hydrogen fuel cell technology is not strictly limited to bus applications. Vision Motor Corporation of Santa Monica is developing hydrogen fuel cell hybrid heavy-duty drayage trucks for goods movement in and around ports. Additional testing, validation, and demonstration are needed to prepare the technology for commercial demonstration or deployment. In order to test the technology for its potential for commercialization, Vision will

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293 California Air Resources Board, *Detailed California Modified GREET Pathway for Compressed Gaseous Hydrogen from North American Natural Gas Version 2.1.* http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.
294 *Full Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts.* Consultant Report. 2007. California Energy Commission, CEC-600-2007-004-REV.

be putting two trucks to work at the ports of Los Angeles in early 2011 for an 18-month project. One "terminal tractor" will be an in-port goods-mover and the other one a big-rig vehicle for moving cargo from the port to short-haul destinations. Both will be operating under real-life scenario conditions. Funding for this battery-dominated hydrogen fuel cell truck commercialization project comes from the ports authorities (some EPA funding from 2010 Clean Air Technologies Award) under the ports' Technology Advancement Program and is being supported by local trucking companies.[295]

A federal tax credit of $10,000 to $40,000 is available for heavy-duty fuel cell vehicles, depending on the weight of the vehicle. The credit may be claimed for vehicles placed in service after December 31, 2005, and purchased on or before December 31, 2014. The SCAQMD also serves as an important funding partner, reserving approximately 13 percent of its $16.6 million in Clean Fuels Program funding for hydrogen and fuel cells. This is mostly intended for research and development in transit and heavy-duty applications, with the goal of improving air quality. Co-funding demonstration/test fleet projects through the AQMDs is already in progress as explained in the ZEB section above. Additionally, ARB is currently reviewing, monitoring and reassessing components of the AQIP to potentially fund and support hydrogen FCBs in future funding plans.

To build on these opportunities, the Energy Commission intends to offer $7 million for the further development and demonstration of new technologies for the medium- and heavy-duty vehicle sector. This funding will extend to a broad variety of advanced technology projects, including hybrid hydraulics, battery electric, fuel cell, but will also consider improvements to gaseous fuel engines and systems.

Table 27: Medium- and Heavy-Duty Vehicles Funding Allocation

Deployment Incentives for Natural Gas Vehicles	$12 Million
Deployment Incentives for Propane Vehicles	$3 Million
Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$7 Million
Total	$22 Million

Source: California Energy Commission

295 Fuel Cell Industry Report, "Vision Motors Testing Fuel Cell Trucks," Volume 12, No.2, February 2011.

Innovative Technologies and Advanced Fuels

The previous sections of this 2011-2012 Investment Plan identified high-priority investments related to specific fuels and vehicles as well as analytical and outreach strategies. The statute establishing the Program also gives the Energy Commission authority to make public investments in opportunities not specifically identified in the annual investment plan including: projects that optimize alternative and renewable fuels for existing and developing engine technologies; control systems and vehicle/fuel integration systems; advanced internal combustion engines that result in at least 40 percent efficiency improvements; lightweight materials; energy storage; battery recycling and reuse; engine and fuel optimization, electronic and electrified components, idle management technology, and aerodynamic retrofits that decrease fuel consumption.

The Energy Commission is interested in developing a program to co-fund discrete projects that accelerate the development and commercialization of technologies and systems that might include strategies to:

- Improve the efficiency of petroleum- and nonpetroleum-fuel engines to increase fuel savings and GHG emission improvements above the current levels (20-30 percent) in electric hybrid and hydraulic hybrid vehicles.
- Improve the design of key vehicle components including high-pressure fuel tank designs, compressors, electronic controllers, motors, fuel cells, batteries, and other components to increase vehicle performance and efficiency.
- Improve the design of key alternative fuel infrastructure components including above and below-ground fuel storage, dispensers, and safety systems.
- Improve vehicles operations through improved controls and on-board diagnostics.
- Integrate smart grid electricity systems with electric vehicle recharging.
- Develop performance tests, instrumentation, drive cycle protocols, accelerated durability testing, and other technology applications to lower cost and shorten time required to comply with engine, fuel, and vehicle certifications.
- Develop alternative materials and production processes for advanced vehicle battery manufacturing and stimulate business practices that encourage the use of vehicle battery and other storage technology in secondary markets and recycle/reuse opportunities.
- Develop high-productivity biomass feedstocks, such as algae and perennial grasses, which can offer significant GHG benefits and be used to produce “renewable crude oils” or gasoline and diesel fuel substitutes.
- Develop low-carbon intensity aviation fuels.
- Develop or demonstrate renewable methanol fuel.
- Lightweight materials that have application across multiple vehicles platforms.
- Demonstration of personal rapid transit systems.

Projects could include feasibility studies, market research, early market demonstrations, competitions, performance and certification tests, incubator programs, X-PRIZE Foundation and other similar awards,[296] research consortiums such as "Centers of Excellence," recruitment of financial investors or a combination of such activities.

Additionally, the federal government is increasingly providing funding opportunities for innovative low-carbon fuels and vehicle technology research, development, and deployment through agencies such as U.S. DOE, U.S. EPA, U.S. DOT, and the USDA. California's ability to capture these funds will rely significantly on the ability of the state to partner with organizations and institutions to develop and cost-share proposals to the federal agencies.[297]

The Energy Commission allocated a combined $8 million for these activities in the previous fiscal year; however, no firm commitments on this funding have been made yet. The Energy Commission does not intend to provide further funding at this point.

296 The X PRIZE Foundation is an educational nonprofit organization that promotes public competitions to encourage accelerated technological development.

297 The Energy Commission will also consider funding for highly leveraged proposals with local governments.

Chapter 3: Manufacturing

Encouraging manufacturers of PEVs and their components to locate or expand their operations in California has the potential to create thousands of green jobs and substantial benefits to the state's economy. For example, at its peak production before it closed in early 2010, the New United Motor Manufacturing, Inc. (NUMMI) plant in Fremont, California, employed 4,500 high-skilled laborers and up to 35,000 supply chain workers in a joint venture between GM and Toyota. California-based Tesla Motors Inc. bought the NUMMI plant in order to expand their in-state manufacturing capacity.

Several California manufacturers produce batteries and component parts for automakers, components for the electronics industry, electric vehicle charging stations, and stationary power storage systems for military and industrial customers. In addition, several start-up vehicle manufacturers have emerged in California and begun developing prototype and early market PEVs. However, difficulties in raising upfront capital can impede these manufacturers from developing and expanding the plants and assembly lines to make advanced PEV components and produce electric and alternative fuel vehicles for commercial sales.[298]

Large vehicle manufacturers have made many capital-intensive investments in alternative fuel vehicle and component production capacity in recent years. These corporate investments have been bolstered by large-scale financial support from the federal government in the form of grants, loans, and loan guarantees. Under the DOE's Advanced Technology Vehicle Manufacturing (ATVM) program, $8.5 billion was loaned to companies such as Fisker Automotive, Ford Motor Company, Nissan, and Tesla Motors.[299]

Most manufacturers in California, however, do not have the funds required to invest tens or hundreds of millions in facility improvements, or the size to attract federal support. They rely on a combination of venture capital, commercial credit, and state and local incentives to fuel their growth. The availability of state and local incentives, therefore, can play a large role in determining where companies locate their manufacturing facilities. By offering Program funds in support of manufacturing, the Energy Commission can ensure California attracts and retains vibrant, job-producing, and sustainable manufacturing facilities.

Using FY 2008-2010 program funding, the Energy Commission awarded $19 million for a combination of grants for pre-development stages of manufacturing plants and loans to help finance assembly and production plants that make vehicles, batteries, electric propulsion systems, and other components in California. This solicitation encouraged investment in California-based manufacturing and assembly plants that produce alternative fuel vehicles and

298 Although the U.S. DOE awarded nearly $1.7 billion nationwide for vehicle and battery manufacturing incentives, no California firm was selected for federal ARRA economic stimulus funding. However, the ARRA funds that were awarded nationwide will still have a large impact on the nation's ability to manufacture electric vehicles and components and will in turn impact California's market for electric drive vehicles.

299 ICF Report, draft consultant report, *Analysis of Alternative Fuel and Vehicle Investments.*

components that help the state meet its GHG emissions and petroleum fuel demand reduction targets. In addition to making grant and loan awards, the Energy Commission will support California manufacturing by collaborating with the CAEATFA to establish loan mechanisms and facilitate sales tax exemptions for the purchase of equipment to manufacture ZEVs.

The Energy Commission reviewed a number of worthy responses to PON-09-605, Manufacturing Plants, which was designed to cost-share the development and expansion of manufacturing and assembly plants in California that produce electric vehicles, alternative fuel vehicles, and batteries and component parts for electric and alternative fuel vehicles.[300] Below is a list of the successful applicants and a brief description of their proposed projects:

- Boulder Electric Vehicles will produce MD/HD electric vehicles from their 20,000 square foot manufacturing facility in Los Angeles
- Coulomb Technologies will design and manufacture their Charge Point Communications Processor, which allows existing electric vehicle chargers to be retrofitted with smart grid connectivity
- Electric Vehicles International will develop, test, and improve an automated, pilot, electric vehicle production process that realizes cost savings by bringing many parts of a diverse supply chain under one roof
- Green Vehicles will install a 2,000 vehicle per year assembly line in their Salinas facility in order to manufacture a three-wheeled highway capable electric vehicle, the Triac
- Leyden Energy will develop and test a new lithium-ion battery technology, and build a pilot production line that is capable of assembling electric vehicle battery packs
- Mission Motor Company will develop their battery module and motor control systems and install a manufacturing line capable of producing 30,000 battery packs and control systems per year by 2015
- Quallion is developing a pilot-scale automated production line that will allow for the large-scale manufacturing of lithium-ion battery modules
- Quantum Fuel Systems Technologies Worldwide, Inc. will re-tool one of its Lake Forest, CA facilities in order to develop, test, and produce a combination inverter/charger for hybrid-electric vehicle applications
- Transpower is studying the feasibility of constructing a manufacturing facility for class 8 electric trucks in California by 2013
- Wrightspeed will validate a new electric drive retrofit kit for class 3 through class 6 trucks, which includes a range-extending micro-turbine generator
- Zero Motorcycles will design and bring to pilot production a new advanced electric motor and integrated controller for use in next-generation electric vehicles

Through PON-09-605, the Energy Commission has made substantial investments in California alternative fuel vehicle and component manufacturers. These investments support manufacturers as they develop products and install pilot-scale assembly lines in preparation for full commercial-scale production. Successful projects will attract customers and receive

300 As part of its earlier ARRA cost-sharing solicitation, the Energy Commission is also providing $1 million toward a project to develop advanced anodes and cathodes that will increase the energy density of lithium-ion batteries.

production orders, and will soon be in need of greater manufacturing capacity. State support can help ensure that these commercial-scale manufacturing plants are located in California with their attendant jobs, environmental benefits, and tax revenue. Therefore, in FY 2011-2012, the Energy Commission will allocate $10 million to fund projects that establish commercial-scale alternative fuel vehicle and component manufacturing facilities in California.

Table 28: Manufacturing Funding Allocation

Manufacturing Facilities and Equipment	$10 Million
Total	$10 Million

Source: California Energy Commission

Chapter 4:
Workforce Training and Development

Workforce development and training is a critical element in the Energy Commission's efforts to develop California's clean transportation market. Training is required to respond to new technology, improve efficiencies, minimize wastage, and reduce the cost of production. Skilled workers are needed to manufacture low-emissions vehicles and components, produce alternative fuels, build fueling infrastructure, service and maintain fleets and equipment, and inform on-going innovation and refinement to increase market acceptance. As the Energy Commission funds alternative fuel and low-emission vehicle projects, it is critical that funds are allocated to assist in the development of a skilled workforce to implement and sustain those projects.

Workforce Development and Training Implementation

A combined $16 million was allocated to support workforce development and training in the first two investment plans. The funds were utilized to establish interagency agreements with Employment Development Department (EDD), the California Community Colleges Chancellors Office (CCCCO), and the Employment Training Panel (ETP). The interagency agreements have been structured to fund alternative fuel and low-emission vehicle training as a portion of the partner agency's broader workforce projects. This approach serves to ensure that program funds supplement workforce training programs to include training consistent with the program investment plan.

This funding structure has required a concerted effort by Energy Commission staff and partners, to identify those elements within each training project that best suit the mission and goals of each funding source. Partner agencies provide traditional workforce training services and basic fuel and vehicle training and program funds are used to support advanced training in alternative fuels and vehicle technologies. While this approach is not a common model in the workforce training system, the strategic alignment of multiple agency's goals and resources has served to leverage limited funds and better serves the multifaceted workforce training needs of the alternative transportation industry and individuals alike.

Workforce development and training grantees have developed programs that establish or expand regional partnerships with Local Workforce Investment Boards, Community Colleges, local training organizations, public/private employers, community and business development organizations, labor organizations and other key stakeholders to address the workforce training needs of the industry within their region, based on the fuels and vehicle technologies adopted.

To date partner agencies have awarded over $7.9 million in program funding, which includes four regional industry cluster assessment and planning grants, eight regional training grants, and eight employer training contracts; to train over 3,500 individuals.

These grants and contracts have secured over $8.7 million in non-state matching funds. Partner agencies have also conducted an industry assessment and developed the Green Transportation Jobs Report, which provides a transportation-focused analysis of the Green Jobs Survey.

Through these partnerships with California's education, training, workforce development, and economic development professionals the Energy Commission leverages Program resources and augments workforce training programs to meet the evolving workforce training needs of California's developing clean transportation industry.

Workforce Training Activities

California Employment Training Panel

The Employment Training Panel (ETP) provides financial assistance to California businesses to support customized worker training. The ETP plays an important role in California's workforce system by assisting businesses in providing lifelong learning opportunities to their incumbent and new hire workers.

The ETP was allocated $5.78 million to fund performance-based training contracts that provide workforce training related to alternative fuels and vehicle technologies that are consistent with the priorities established in this investment plan.

The ETP interagency agreement was finalized in June 2010. ETP wasted no time; they immediately funded five training contracts before the close of the 2009/2010 Fiscal Year. Due to delays resulting from the extended period without a state budget they were not able to fund additional projects until January 2011. Three program related contracts were awarded during their January Panel Meeting for a total of eight training contracts totaling $4,172,830 to train over 2,400 individuals and secured over $4.5 million in non-state match (Table 29).

Table 29: Employment Training Panel Funded Training Contracts

Contractor	Program-Related Training Focus	Number of Trainees	Program Funding	Non-State Match
Terex Utilities[%]	Installation, service and maintenance training related to HyPower aerial device.	44	$158,400	$242,644
ISE Corp[%]	Hybrid drive vehicles; lean manufacturing; quality control ISO 9001	126	$453,600	$546,084
Electric Vehicles, Inc[%]	MD and HD electric drive vehicles	100	$494,000	$315,000
Fillner Construction[%]	Alternative fuels fueling Storage	28	$149,240	122,500
*California Manufacturers & Tech Assoc (CMTA)	Hydrogen fuel cell; Alt fuels; hybrid electric lean manufacturing; production solutions; quality controls	305	$559,060	$900,000
**California Labor Federation (CLF)				
Blue Sky Bio-Fuels	San Francisco	19	$59,280	$56,883
MV Public Transportation	Alameda, Los Angeles, Tulare	100	$180,000	$200,000
California Labor Federation	Sacramento, Santa Clara Valley, Los Angeles Regional Transits	1,750	$2,119,250	$ 2,200,000
Totals		2,472	$4,172,830	$4,583,111

Source: California Energy Commission

*CMTA is a multi-employer training contractor that supports training for multiple companies, which may include: Altergy Systems, Pacific Ethanol, Peterson Power, and Cummins West

**CLF is a multi-employer training contract that will provide training for multiple companies, which may include: Sacramento Regional Transit District, and Santa Clara Valley Transportation Authority

[%] Program development or deployment project grantees

California Employment Development Department (EDD) and California Workforce Investment Board (CWIB)

The EDD operates one of the largest public employment services operations in the world. The Job Service program offers resources at hundreds of locations throughout the state and connects one million job seekers with employers each year, through their comprehensive One-Stop Career Centers. These regional centers provide access to a full range of programs pertaining to educational activities, local employer services, and referrals to other appropriate social services. EDD delivers pre-paid training and employment services to unemployed, under-employed, and incumbent workers and helps employers connect with skilled workers.

EDD and CWIB have awarded eight local workforce training programs and four regional industry cluster planning and implementation program grants related to alternative fuels and vehicle technologies consistent with the investment plan. These 12 grants totaled over $3.9 million in program funds and attracted over $6.3 million in non-state match.

Table 30: EDD 2009 Local Workforce Subgrants

Grantee	Partner	Sample of Industry Participants	Training Sample	Number of Trainees	Program Award/ Match
Los Angeles Co. W	Los Angeles Community College District	General Motors, Miles Electric Vehicles	Alt Fuel and Electric Vehicles	64	$400,000/ $975,000
Pacific Gateway WIB - Long Beach	Long Beach City College	Port of Long Beach, City of Long Beach Fleet Services Bureau	Hybrid / Electric Natural Gas Heavy-Duty Vehicles	150	$400,000/ $813,059
City of Richmond; Richmond Works	Peralta College District & Contra Costa College	AC Transit, Toyota	CNG and Electric Drive Vehicles	100	$400,000/ $834,000
Sacramento Employment and Training Agency	American River College	SMUD PG&E	Bio-Diesel, Natural Gas/Hybrid /Electric Vehicles	120	$400,000/ $641,610
Imperial County Workforce Development	On-Site Multiple Employers	SunEco Energy, Carbon Capture Corp, Biolight	Bio-Fuel Production	60	$400,000/ $709,593
Orange County Workforce Investment Board	Cypress Community College and Society of Automotive Engineers International	Society of Automotive Engineers International and Orange County Business Council	Heavy-duty CNG, fuel cell, hybrid, and electric drive vehicle technologies	150	$500,000/ $550,000
Solano Community College (multiple locations)	Solano Workforce Investment Board (multiple locations)	Green Employer Council Bay Area EV Corridor Network	Hybrid and electric drive vehicle technologies	400	$500,000/ $503,692
Northern Rural Training and Employment Consortium	Regional Community Colleges – CSU Chico	PERC; National Propane Gas Association Roush CleanTech	Hybrid and propane vehicles	136	$500,000/ $525,000
Totals				594	$3,500,000 /$5,52,929

Source: California Energy Commission

CWIB Regional Industry Cluster of Opportunity (RICOG)

The Energy Commission partnered with the CWIB to fund four regional industry cluster of opportunity planning and development projects related to alternative fuels or low-emission vehicle technology. The CWIB RICOG initiative is a structured economic and workforce development planning process that brings regional economic and workforce development practitioners and industry together to develop data-based regional strategies to support and advance the competitive position of targeted industry clusters (Table 31).

The RICOG process consists of four phases, which include:[301]

- Clusters of Opportunity Diagnosis*:* Research and analyses to identify regional industry clusters.
- Collaborative Priority-Setting***:*** Design and implementation of a collaborative cluster engagement plan based on results of the research and analyses.
- Cluster of Opportunity Investment Strategy**:** Identify and connect specific investments and other commitments to advance the competitive position of regionally targeted clusters.
- Sustainable Implementation***:*** Support the long-term sustainability and growth of regional clusters.

Table 31: CWIB Clean Transportation Regional Industry Cluster Opportunity Subgrants

Grantee	Counties	Program Funding	ARRA Match
Pacific Gateway – Long Beach	Los Angeles, Orange, and Ventura	$49,987	$200,000
San Bernardino County	Riverside & San Bernardino	$49,000	$200,000
Santa Barbara County	San Luis Obispo, Santa Barbara and Ventura	$50,000	$200,000
Northern Rural Training and Employment Consortium (NorTec)	Butte, Del Oro, Lassen, Modoc, Nevada, Plumas, Shasta, Sierra, Siskiyou, Tehama, and Trinity	$49,000	$200,000
Total		$197,987	$800,000

Source: California Energy Commission

As an example of a RICOG grant, the Northern Rural Training and Employment Consortium (NorTec) is developing a regional action plan to support propane auto gas market development within their 11 county region. Propane has been selected as one of NorTec's industry clusters due to regional familiarity and comfort with the fuel, wide spread use of Propane in other applications, and the industry's interest in developing the propane auto gas market. NorTec's propane auto gas regional action plan is being developed in partnership with vehicle manufacturers/suppliers, fleets, municipalities, service and maintenance providers, fuel and infrastructure suppliers, community colleges, universities, and economic, business, and workforce training agencies. The full market approach, including both the supply and demand side of this market, being adopted by NorTec should serve to provide a text book example of successful implementation of the RICOG sector strategy approach to economic and workforce development.

301 California Workforce Investment Board, "Fact Sheet: Regional Industry Clusters Opportunity Grant," http://www.cwib.ca.gov/page/library/RICOG_Fact_Sheet.pdf

California Community College

California Community College system is the largest higher education system in the nation. It is comprised of 72 districts, 112 colleges and enrolls more than 209 million students.

The Community Colleges' Chancellor's Office (CCCCO) has been allocated $4.5 million to assess industry need, existing training alternative fuel and vehicle courses currently available, the need for training course development, the development of needed courses, and development of instructor training and course materials.

CCCCO completed the industry assessment in 2010. Findings are represented under Workforce Demand below.

Workforce Demand

These partnership and outreach efforts have provided access to regional training service providers, transit agencies, OEMs and fleets providing on the ground information to inform workforce planning for the coming year.

Industry and workforce training partners alike are reporting a mounting skilled workforce gap resulting from the combined impact of the economic downturn, reduced training resources, and the aging workforce; these challenges are compounded further with the current need for a workforce trained in advanced transportation technologies. An example of industry and partner input on the need for workforce training assistance is provided below:

Transit

- The transit sector is experiencing significant technological change along with the retirement of existing workers. New technology designs in bus systems relating to alternative fueled engines, hybrid buses, multiplex systems, and on-board diagnostic panels created the need to improve technician's diagnostic skills to maintain new bus fleets.
- Today's technicians use computers in their daily work on public transit vehicles. Operators and mechanics use laptops, scanners, programmers and electronic communication devices to diagnose these new sub-systems in transit buses and rail vehicles. These trends are resulting in skill shortages, particularly in vehicle maintenance occupations.[302]
- The Southern California Regional Transit Training Consortium (SCRTTC) Workforce Needs Assessments[303] report transit technician skill gaps in basic electrical, basic electronics, basic computer skills, troubleshooting skills, diagnostics and software analysis, specific vendor supplied training, computerized engine controls, plus the ability to read schematics and locate and interpret technical manuals and specifications.

A sampling of Program-related training needs includes the following:

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302 Based on discussions with regional transit agencies and statewide and regional workforce training partners

303 Excerpts from the SCRTTC Transit Workforce Needs Assessment Update 2009

- Electronics Systems for Transit; include troubleshooting and schematics
- Network Electronics Diagnosis and Repair; inclusive of Multiplexing
- CNG Computerized Engine Controls
- Hybrid Electric Transit Training
- Hybrid Transit Safety Training
- CNG Transit Safety Training[304]

Electric Vehicle Manufacturer

The recent Take Charge California Report states that while the state has a skilled workforce and currently faces high unemployment, additional workforce training is needed to prepare employees for the burgeoning "green" economy and to attract PEV-related manufacturing to the state. The report goes on to suggest that workforce training to support growing PEV markets should be incorporated into current training programs using existing partnerships.[305]

Tesla recently communicated that their most pressing need was to find assistance to fund workforce training for 500 immediate hires and 1,000 near-term workers they plan to hire to begin production on the Model S.

In 2010, Tesla purchased a part in the NUMMI plant, (Fremont, California) in order to expand their in-state production capacity to produce electric vehicles and components. Tesla products include the Roadster and the Model S, which is expected to rollout in 2012. Tesla's Model S sedan will be the first vehicle produced at the plant with future vehicles to follow in the coming years.[306]

Medium and Heavy-Duty Vehicle Manufacturers

Energy Commission staff recently conducted outreach meetings with medium- and heavy-duty vehicle manufacturers to obtain information on current and planned alternative fueled vehicle roll-outs. The industry is facing a workforce shortage due to the loss of 70 to 80 percent of their journey-level technicians. If they should chose to exit in large numbers this has the potential to create a skills gap. The situation is compounded by the industries adoption of alternative fuel and vehicle technologies. Workforce training development is needed to address this pending skilled workforce shortage. Training must focus on the following:

- CNG certified training for vehicle technicians at 29 California dealerships
- Training for customer vehicle technicians who perform their own maintenance (Caltrans, Ryder, Sysco, etc.)
- Training related to propane vehicle retrofit, service and maintenance

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304 Ibid.
305 Energy Commission staff meeting with Tesla Corporation.
306 Ibid. Tesla products include the Roadster and the Model S, which is expected to rollout in 2012. Tesla's Model S sedan will be the first vehicle produced at the plant with future vehicles to follow in the coming years.

- Hybrid vehicle training for vehicle technicians
- Electric light-rail
- Dedicated electric-drive[307]

Workforce Training Partners

Employers must be able to effectively train workers in response to changing business and industry needs. While the need for workforce training is critical, businesses generally reserve capacity building dollars for highly technical and professional occupations – limiting investment in training for frontline workers who produce goods and deliver services.[308]

Regional training providers report an increase demand in training related to new vehicle rollouts and specifically note an overwhelming need for trouble shooting and diagnostics training for transit vehicle technicians and hybrid and electric-drive vehicles.[309]

Clean Transportation Workforce Research

Clean transportation is a fledgling entrant in California's Green Jobs assessment efforts, which results in a lack of industry focused data to measure the current and near term workforce needs and inform development of the program's workforce training efforts. Current efforts rely on informal survey, stakeholder input, anecdotal information and bits of data pieced together from studies of the larger green economy, which primarily focus on energy efficiency, clean energy, and the building and construction industry.

Three such research efforts focused on California's Green Economy and Jobs are the Next 10 Shades of Green, the California Community Colleges' Chancellor's Office Fleet Training Needs Assessment, and the EDD's Labor Market Information Division (LIMD) Green Jobs Survey. The fleet assessment, developed in collaboration with Energy Commission staff, provides alternative fuel and vehicle dedicated information, while the Next 10 and LMID reports were mined for data related to the clean transportation industry and jobs. The results will be utilized to guide continued development of the workforce training program. A summary of program applicable information is provided below.

Alternative Fuels and Alternative Fuel Vehicles Training Needs Assessment

In Spring of 2010, the California Community Colleges' Chancellor's Office conducted an informal training needs survey with public and private employers throughout California that currently own or otherwise work with alternative fuels and alternative fuel vehicles. The survey questioned employers about their vehicle use, now and in the future; their current occupational employment; and their need for – or interest in – training topics.

307 Based on Energy Commission staff meetings with industry, including International/Navistar, Roush, Kenworth, and Freightliner

308 Employment Training Panel, "2010-2011 Strategic Plan," http://www.etp.ca.gov/packet/Strategic%20Plan%202010-2011.pdf

309 Based on Energy Commission staff discussions with regional training providers

The report provides information on survey efforts and responses from employers are in five geographic regions.

- Los Angeles Region – includes the counties of Los Angeles, Riverside and San Bernardino
- Sacramento Region – includes the counties of Sacramento, Solano, and Yolo
- San Joaquin Valley – includes the counties of Fresno, Kings, Madera, Merced, and Tulare
- Imperial County
- Modoc County

The 65 survey respondents working with fleets statewide are responsible for close to 68,416 vehicles. Of these, almost 21 percent or 14,351 are alternative fuel vehicles. Transit agencies reported the highest concentration of alternative fuel fleet ownership (92 percent of vehicles are alternative fuel), followed by private fleets (48 percent), state government (19 percent), and city/county government (14 percent).

Fleet Alternative Fuel and Vehicles

Employers were asked to provide more detail on the alternative fuel vehicles in their fleets, including fuel types, type of usage, makes and models. Compressed natural gas (CNG) vehicles seem to be the most prevalent choice among these respondents. Fifty-two of the 65 fleet employers operate CNG vehicles. Eleven employers utilize all three light, medium and heavy duty vehicles fueled by CNG; twelve indicated they own a combination of two types of CNG vehicles, while 29 operate a single type.

Hybrid and electric vehicles received the next highest amount of responses among employers (42 and 30, respectively); in both cases, the majority of responses were for light duty usage.

Looking forward, employers indicated the types of alternative fuel vehicles they plan on purchasing in the short-term future (next two years) or long-term future (within three to six years). As in current ownership, the most popular fuel choice for future purchases is CNG, with 38 respondents expecting to add this fuel type in the next two years and 12 respondents anticipating a purchase in the next three to six years.

Repair and Maintenance

Given the large numbers of vehicles these employers need to maintain and repair, it is not surprising that 88 percent reported they support at least some of these services in-house (57 employers). Of these, 71 percent perform all maintenance and repairs needed, while 15 percent limit their on-site shop to maintenance and light repair work.

The majority of fleet employers support general repairs, such as brake repair, lube and oil changes as well as vehicle tune up and diagnostics (54 and 49 employers, respectively). Another 38 employers conduct major repairs on-site, such as engine rebuilds, replacements, and transmission repair. Other comments confirmed that general repairs, preventative maintenance inspections, and select major repairs are subcontracted to vendors.

Only three of the 65 employers responded that they outsource or are currently still under warranty for some or all maintenance and repair work.

Current Employment

To better understand training needs, the survey queried respondents about their current staffing levels and specific occupations in their organizations. Within the sample, 82 employers responded to this question – accounting for 25,197 workers; of these, 41 percent, or 10,271, are estimated to work directly with or around alternative fuels and/or vehicles.

To assess training needs, the survey first asked employers to indicate their immediate need (next 6 months) and their future need (next 2 years) for training across seven broad categories: engine diagnosis and repair, emission systems inspection, high-pressure fuel system analysis, fuel properties, electrical drive systems and battery technologies, first responder safety training, and fuel station maintenance. A majority of employers indicated a need for all seven training areas (a combined need of 53 percent for fuel station maintenance to 87 percent for engine diagnosis and repair and repair, electrical drive systems and battery technologies is most in demand by transit agencies and city/county government, although other groups showed interest as well.

Overall, the surveyed employers have a preference for, or an already established inventory, of three types of alternative fuels and/or vehicles: CNG (and, by extension, LNG), hybrid, and electric. In addition to current ownership, these types of alternative fuel vehicles are consistent with employer plans to increase fleets in the short- and long-term future as well as respondent support for training topics and subject areas that focus on maintaining, repairing, or otherwise working with these fuels and vehicles. These responses are also consistent with the majority of employers who support on-site fueling and on-site repair and maintenance functions.

Green Transportation Jobs Report

As part of the EDD interagency agreement, the Energy Commission tasked EDD's LMID to analyze relevant data from the California Green Economy Survey (Green Survey) that relate to the Program.

The Energy Commission asked for a special focus on the following industrial activities:

- Production, storage, and transportation of renewable fuels
- Green transportation manufacturing, distribution, installation and maintenance
- Sustainable fuel feedstock production and extraction

The LMID used data collected from the Green Survey to support analyses of employment in green jobs and businesses, and green occupations. In addition to analyzing the Green Survey, further research on Program-related occupations helps increase understanding of knowledge, skills, and other variables associated with workforce development for related occupations.

Green business practices reported by firms related to the Program, findings consistent across industry groups include:

- On-the-job training was the most prevalent method for preparing current workers

- Economic conditions and costs of implementation were the greatest barriers to implementing green practices

Program Industry Groups:

In order to analyze the survey data on green industries and green business practices relevant to the Program, LMID needed to relate the Energy Commission's focus areas above to industries, as defined according to the North American Industry Classification System (NAICS). To do this, LMID coordinated with the California Community Colleges' Centers of Excellence and the Energy Commission to develop the following three groups:

- Alternative Advanced Vehicles – 11 NAICS codes
- Alternative Fuels – 13 NAICS codes
- Transportation Systems – 20 NAICS codes

Analysis based on employees working 50 percent or more of their time in a green transportation job reveals an estimated 15,208 jobs in Alternative Advanced Vehicles, 35,546 jobs in Alternative Fuels, and 21,466 jobs in Transportation Systems. This analysis provides a depiction of the extent to which green employment exists in each of the Program industry groups.

Program-Related Occupations

Research focused on 14 occupations relevant to the Program's goals with potential for re-skilling programs. Findings include estimated green employment for the six Program-related occupations included in the Green Survey. The data from the Green Survey also support comparisons of estimated green employment to estimated total employment in California for three established Program-related occupations. In addition to analyzing the survey, employment demand and occupational profiles were developed for each of the 14 Program-related occupations.

The Green Survey results provide employment data on six green transportation occupations. The largest estimated green employment was reported for Industrial Production Managers involved in green activities (more than 20,000 employees), with Alternative Fuel Vehicle Technicians coming in second (more than 19,000 employees). Further, data from the Green Survey show a substantial portion of estimated employment (approximately 30-50 percent) being involved in green activities at least some of the time for the three established occupations of Electrical Engineers, Mechanical Engineers, and Automotive Service Technicians.

In addition to reporting the Green Survey findings, the LMID conducted demand analyses for Program-related occupations by using a proprietary software tool, WANTED Analytics 2.0, *Help Wanted On-line (HWOL)*, produced by WANTED Technologies in conjunction with The Conference Board. While job listings declined for almost every occupation from May 2009 through April 2010 – a period of time encompassing one of the worst economic downturns in a century – job ads for Automotive Service Technicians grew 4 percent in California during this period. While 4 percent may appear low, the occupation is growing and the need for these workers to service and repair the growing number of alternative fuel vehicles is expected to rise as current vehicles age and need servicing.

As a final deliverable to the Energy Commission, and as part of the standard agreement, follow-up focus groups are planned for some of the approximately 5,000 employers who responded to the Green Survey that expressed a willingness to provide additional information about green jobs, associated training requirements, and desirable skill sets. This information will be delivered as an addendum to this report by the end of 2012.

NEXT10 Many Shades of Green Report

The second edition of Many Shades of Green: Regional Distribution and Trends in California Green Economy tracks employment and business growth related to products and service that improve efficiencies in the consumption of all natural resources and reduce negative environmental impacts.[310]

Clean transportation, including alternative fuels and vehicle and equipment, is identified as one of 15 segments of California's Core Green Economy. Clean transportation hubs are emerging in Orange County, the Bay Area, San Diego, and the Inland Empire, but activities associated specifically with fuels and vehicles are showing up in different places.

Regional Trends

Los Angeles Area: The Los Angeles Area is one of the state's hot spots for clean transportation, increasing 33 percent since 1995 and nine percent between January 2008 and 2009. In particular, the region has a high concentration of employment in motor vehicles & equipment which witnessed a leap of 11 percent in jobs in the recent single-year period.

Orange County: Orange County is a leader in the clean transportation in the vehicle sector as well as well as the Alternative Fuels sector. With employment shares 2.1 times higher that the state average, the region reflects a mounting strength in Clean Transportation, building from expertise in its conventional auto industry. Motor vehicles and equipment is driving much of this growth, increasing employment by 116 percent (450 jobs) from 1995 to 2009.

San Diego Region: Clean transportation employment growth accelerated by a factor of six between January 1995 and 2009. Establishments grew at a similar rate during that time. Over half of the employment in this segment is in Alternative Fuels. Employment in sub segments soared from under 50 to over 350 between 1995 and 2009. Primarily in Imperial County, alternative fuels are taking off: employment expanded over 700 percent between 1995 and 2009.

Inland Empire: In clean transportation, the Inland Empire has become a leader in Alternative Fuels with employment shares nearly triple the statewide average. Overall clean transportation employment increased 42 percent over the 15 years. The merger of two locally-based electric vehicle companies resulted in employment losses in the nineties. The employment jump in 2002 was the result of a cheap producer leveraging its wastewater for the production of biofuels. New jobs created in 2008 following formation of a new electric vehicle company.

San Joaquin Valley: Clean transportation employment more than tripled from 1995 to 2005. With an employment concentration 50 percent above the state average, this segment represents

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310 Next 10, *Many Shades of Green: Diversity and Distribution of California's Green Jobs,"* January 2011, http://www.next10.org/next10/publications/green_jobs/2011.html

an important regional strength. Growth has been driven in most part by Alternative Fuels, which accounts for 85 percent of employment in clean transportation. Alternative fuel employment is three times more concentrated in the San Joaquin Valley than in the state as a whole and grew 364 percent from 1995 to 2009.[311]

2011-2012 Workforce Training and Development Plan

The Energy Commission intends to provide $5,000,000 for additional implementation of workforce training and development. The Energy Commission staff will continue to work with partner agencies, California business, labor, local economic development, and other stakeholders to provide access to workforce training resources, to obtain timely information on current and evolving workforce training needs, and to develop and refine training delivery systems that provide a well-trained workforce to support the development and deployment of alternative fuels, infrastructure and vehicles.

This effort will utilize existing partnerships and funding to complete the efforts and goals formalized in the last investment plans; and allocate funds to support additional workforce training contracts and support workforce training program development.

California Community College Office of the Chancellor

The CCCCO will utilize grant funds remaining available (approximately $3 million) to fund curriculum development, train-the-trainer instruction, training equipment, and development of training materials to meet the immediate program related training needs of Program Community College grantees (funded through the EDD IA). In addition, the CCCCO will develop training modules for those areas identified through the industry assessment for community colleges (non-Program grantees) that have identified demand for program related training. The training modules developed will be made available to community colleges throughout the state with similar programs and/or regional workforce training needs.

The CCCCO will utilize grant funds remaining available ($575,000) to provide occupational and industry information to identify training needs by region. CCCCO will also prepare environmental scan reports to provide regional workforce information for use by community colleges in program planning and resource development. In addition, CCCCO will prepare a draft Community Colleges Assessment report that will itemize the training and instructional needs of each college in need of a program, along with training and instructional resources in existence within the community college network/system.

These reports will guide development and refinement of the Program's workforce training efforts, and inform future investment planning.

Employment Development Department

EDD will continue to assist regional and community college grantees in achieving their workforce training goals, as established in their Program-funded workforce training grants, to ensure that regional workforce training needs related to the program are being addressed.

Utilizing grant funds remaining available ($300,000)in the EDD/Energy Commission interagency agreement, EDD will work with Energy Commission staff and workforce training

311 Shades of Green Report – 2011 Update - Release January 2011

partners to develop a plan to deliver workforce training related to 2011 vehicle rollouts through existing workforce training grantees.

To be eligible for additional funds grantees must:

- Demonstrate a new or unmet training need, which was not addressed in the original grant
- Have demonstrated successful performance under the original grant
- Establish partnerships with at least one training provider; with the capacity to provide training in clean alternative fuels and/or vehicles and with one employer; who employs workers in the development and/or deployment of clean alternative fuels and/or vehicles.

California Workforce Investment Board

CWIB will continue to work with the Energy Commission's funded RICOG grantees to finalize development of regional sector strategies related to alternative fuels and vehicles. Working in collaboration with Energy Commission staff, CWIB will utilize funds remaining available ($300,000) to support RICOG grantees in the implementation of regional action plans that support long-term sustainability and growth of an alternative fuel and/or vehicle regional cluster.

Only those grantees that develop a regional action plan, which addresses all aspect of the market chain, will be eligible for additional funding. Fundable action plans would include partnerships and commitments in the following market elements:

- Vehicle manufacturers/suppliers
- Vehicle market demand/purchase commitments
- Fuel producer/supplier
- Fueling infrastructure
- Economic Development
- Business Development
- Workforce Development and Training Agencies

Each region awarded implementation funds will provide sector strategy related data, which at a minimum will quantify and include:

- Vehicles deployed
- Increase in alternative fuel consumption
- Decrease in traditional fuel consumption
- GHG reductions
- Number of Jobs Created or Retained
- Number of Trainees Trained
- Number of instructors trained
- Businesses served (vehicles purchased, fueling infrastructure installed, workforce trained)

Workforce Development and Training Outreach

One of the primary workforce training goals of the coming year will be to increase the level of connectivity between existing Program fuel and technology projects and industry requests for training with the training resources available through Energy Commission's partner agencies and training delivery grantees. Toward this end, the Energy Commission intends to allocate $250,000 for outreach in expanding workforce development and training.

Agency Partners

ETP has developed a marketing plan to get the word out to the clean transportation industry on the availability of Program workforce training funds. They also work closely with Energy Commission staff to respond to requests for workforce training assistance received by the Energy Commission. ETP, with over 20 years of reputation building performance, is well positioned to get Program training funds out into the clean transportation industry. Even greater Energy Commission staff resources will be rededicated to working with ETP partners to ensure that funding is accessible to the alternative fuel and vehicle industry.

The EDD and Energy Commission-funded Community College grantees and local workforce investment boards provide the opportunity for outreach on a statewide, regional, and local basis. Workforce training opportunities and information on industry workforce needs flow in both directions with these leading workforce and training agencies. Local and regional need are often times communicated at the local level and communicated up to the state level for funding consideration or strategic planning, while statewide initiative and funding opportunities are communicated out to local workforce boards and one-stops who inform local businesses. The Energy Commission will work with EDD and community college partners to develop an outreach and marketing plan to increase awareness of training resources available to support clean transportation industry workforce needs.

Industry partners

Engage industry and stakeholders to obtain real time and projected workforce training needs, to identify specific skill set needs, guide curriculum and training program development, improve access to training resources, and to inform future workforce investment.

In addition, based the recommendation provided by Barbara Halsey, Executive Director, California Workforce Investment Board, during the 2010/11 investment planning effort, Energy Commission staff will collaborate with the California Workforce Investment Board's Regional One-Stop Business Services, Small Business Development Centers, and the Governor's Office of Economic Development to increase small and medium-sized businesses awareness of workforce training and other program resources available to assist them in their transition to clean transportation.[312]

Employment Training Panel

The ETP will utilize grant funds remaining available ($1,182,170) to fund workforce training contracts to support training related to alternative fuels and vehicle technologies.

312 Comments submitted by the California Workforce Investment Board, Energy Commission Docket Number 09-ALT-1, April 1, 2010.

The Green Transportation Jobs and Next 10 reports informed us that 79 percent of employers prefer on-the-job training, where the curriculum can be tailored their specific production process needs while minimizing production disruption. The partnership with ETP supports training identified by business/industry that can be delivered at the employer's worksite.

ETP has received inquiries from companies interested in funding to support alternative fuel and vehicle technology training. With the level of interest expressed by the employer community, combined with ETP's marketing efforts, it is anticipated that the initial $5,780,000 million allocation will be obligated in contracts before the close of the 2010-2011 fiscal year. Additional funds are required to meet the workforce training needs of businesses engaged in the development and/or deployment of alternative fuels and vehicle technologies.[313]

Future Planning

Energy Commission staff will work with education departments, workforce training agencies, and stakeholder groups to identify possible programs geared to develop career ladders for new entrants to the industry and address white-collar workers training needs related to alternative fuel and vehicle technologies. An assessment of these populations relative to workforce demand and identified skill needs will be built into the dedicated transportation research effort described below.

Workforce Development and Training Demand Research

In order to develop effective workforce programs, to address immediate workforce needs, and to inform long term planning, information must be compiled on types of alternative fuel and/or vehicle technology being adopted by each region, where clean energy jobs will be located and what skills are needed to meet the needs of those industries.

The Energy Commission will allocate $250,000 to solicit for research services dedicated to quantifying workforce training needs of the alternative fuel and vehicle industry. The information obtained through a clean transportation research effort will shape the program's workforce training efforts and inform future funding allocation assessments.

Table 32: Workforce Development and Training Funding Allocation

Workforce Training Delivery	$5 Million
Workforce Outreach	$0.25 Million
Dedicated Clean Transportation Workforce Needs Study	$0.25 Million
Total	$5.5 Million

Source: California Energy Commission

313 Letter from Brian McMahon, Employment Training Panel, dated June 27, 2010.

Chapter 5: Market and Program Development

Outreach and Marketing

An essential component for achieving the program goals is getting information out to the various enterprises as incentives and financing options become available. Businesses discouraged by the sluggish economy and wanting to leverage their costs of development and commercialization plans toward cleaner transportation systems need to be aware of funding opportunities that can benefit them. The developers of the AB 118 legislation had the foresight to include market-critical activities like outreach and marketing into the program to ensure its success in advancing California's transportation.

So far, the most visible method of public marketing and outreach has been a series of workshops held by the Energy Commission during the development of the Investment Plans and those describing guidelines for the various funding opportunities and solicitations. As the number and types of funding mechanisms increase and funded projects progress into self-sustaining marketing concerns, the need for up-to-date program information and news is intensified.

Communication Plan

In 2009, when Energy Commission staff refined the communications plan, the stage was set for the 2010-12 launch of the Program's media and marketing campaign. Working within the Energy Commission's internal Media and Public Communications Office (MPCO), and collaborating with key agency partners, marketing materials such as fact sheets, brochures and press kits are being developed to offer simple, straightforward details about the program and highlight the funding priorities identified in the Investment Plan and provide links to more detailed information via the Program's website and partner/stakeholder sites. The MPCO also coordinates press releases to announce program opportunities and events and to feature up-to-date program milestones and success stories.

Website Redevelopment

In 2010, Energy Commission staff, in recognition of the importance of providing the public up-to-date information on program activities and opportunities and providing the most current information on the fuels and vehicle technologies the program supports, began redesigning the program website to facilitate easier access to program and technology information. The first phase of this undertaking, launched in early 2011, enables interested people to quickly find basic information about the program, the types of projects that are being funded, and opportunities for financing or other incentives. The Program site offers users easy access to agencies and programs such as California Air Resources Board's Drive Clean Campaign and the Bureau of Automotive Repair's Drive Healthy information site and others promoting related projects or events. Additionally, in compliance with SB1455, the site also includes links to local publically-owned electric utility companies to provide consumer information about charging infrastructure for PEVs. The Energy Commission anticipates that the website redesign will be completed by July 2011 and content will be updated on a monthly basis thereafter.

Marketing and Media Solicitation

A multi-media campaign is required to reach the wide range of businesses, fleet managers, universities, elected officials, air districts, environmental organizations and early adopters targeted in the investment plan. The services of an outside public awareness and marketing firm will be secured to develop audience and regional -specific print, radio, television, and cable ads and to negotiate media buys that maximize exposure to these targeted audiences. The selected firm will also work with the Energy Commission's staff to develop metrics and tools to measure the campaign's effectiveness.

Alternative Clean Transportation EXPO 2011

In May 2011, the Energy Commission will sponsor and participate in the Alternative Clean Transportation (ACT) Expo 2011. This nationally publicized event targets advanced transportation industry officials, government and policy professionals, legislators, public and private fleet administrators and consumers. The Expo is expected to bring together a wide range of national and state businesses and other groups influencing the growth of the advanced transportation industry sharing the latest information on funding opportunities, regulatory policies, and inside details on new and emerging technologies. The conference will give the Energy Commission an opportunity to showcase the Program and could potentially bring new and innovative projects in under future funding opportunities.

The FY 2011-12 Investment Plan allocated $2.5 million to support Program marketing and public outreach activities. The goals and activities described in this investment plan will be supported utilizing funds remaining available from the 2010-2011 investment plan allocation. No additional allocation for program marketing and public outreach is required in this round of investment planning.

Standards and Certification

The Energy Commission is reviewing the need for funding in this area.

Sustainability Studies

The Energy Commission is the first major government energy agency in the country to make transportation energy project funding decisions based on specific sustainability goals and evaluation criteria. The Energy Commission is required to "establish sustainability goals to ensure that alternative and renewable fuel and vehicle projects, on a full fuel-cycle assessment basis, will not adversely impact natural resources, especially state and federal lands." In response to this statutory directive, the Energy Commission developed the following sustainability goals[314] to identify and promote transportation-related GHG reduction projects that are exemplary in sustainability and environmental performance and that can serve as national and international models:

- The first sustainability goal is the substantial reduction of life-cycle GHG emissions associated with California's transportation system to help meet California's 2020 and

314 The implementing regulations for ARFVT include 13 sustainability evaluation criteria that are used by staff during review and evaluation of proposals submitted for funding.

2050 targets as defined in Health and Safety Code Section 38550 and the Governor's Executive Order S-03-05.

- The second sustainability goal is to protect the environment, including all natural resources, from the effects of alternative and renewable fuel development and promote the superior environmental performance of alternative and renewable fuels, infrastructure and vehicle technologies.
- The third sustainability goal is to enhance market and public acceptance of sustainably produced alternative and renewable fuels by developing, promoting, and creating incentives for the production of such fuels in accordance with certified sustainable production practices and standards as established by government agencies, academic institutions, and nongovernmental organizations.

Biofuels (referred to as renewable fuels under the federal RFS) are projected to play a critical role in meeting the GHG reduction goals for the state's transportation sector, and the production and use of biofuels must grow substantially to meet RFS fuel use requirements. The Energy Commission recognizes that the transition to large volumes of alternative and renewable fuels needed to help meet the state's GHG reduction goals from the transportation sector must be managed properly to avoid environmentally and socially destructive production practices.

The potential for indirect land use change effects from biofuels production as emerged as a proxy for sustainability concerns about biofuels produced at industrial scales from purpose grown energy crops such as corn, soy, oil palm and sugarcane. As described in the previously referenced paper from Holly Gibbs of Stanford, approximately 100 million hectares of land have been cleared and developed for plantations, much of which has occurred in tropical zones. Brazil, Indonesia and Malaysia now account for 40 percent of global soy, oil palm and sugarcane production.

Estimating indirect land use change values from energy crop production is a legally and methodologically complex endeavor, as evidenced by the work of the ARB's Expert Workgroup during 2010. ILUC values do not directly address primary issues of concern, such as tropical deforestation, loss of high quality ecosystems and their dependent species of fauna and flora, water pollution, or air pollution. Energy Commission staff encourage ongoing support and investigation into alternative systems for conservation of sensitive, high carbon and high habitat quality lands at risk of loss from bioenergy crop production.[315] For example, the United Nation's REDD program (Reducing Emissions from Deforestation and Forest Degradation) needs ongoing development. The United Kingdom and European Union are also evaluating alternative approaches that would identify and preserve high carbon and high habitat quality lands and disqualify any biofuels produced from such land types from receiving advanced biofuels credits in Europe.[316]

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315 Jim McKinney, Energy Commission Staff Representative to the Expert Workgroup, oral comments at November 5, 2010 Expert Workgroup Meeting.

316 Paul Hodson, European Commission, Presentation to the ARB Expert Workgroup, February 26, 2010.

When AB 118 was being drafted in the State Legislature, there was strong concern that in-state energy crop production could displace prime farmlands used for primary human food production, or could result in large acreages of grasslands or forestlands being converted to energy crop production. The ARFT sustainability goals and evaluation criteria were crafted to ensure that no Program money was allocated to projects with such potential. Neither phenomena has occurred, and several project proposals with non-sustainable features were not funded.

The Energy Commission supports the development of an environmentally sustainable in-state bioenergy industry so that California can benefit economically from in-state biofuels production from the waste-based feedstocks and alternative purpose grown energy crops described earlier.

For internationally produced biofuel feedstocks, Energy Commission staff continues to assess the major international initiatives and sustainable certification programs that are in development. The Energy Commission is working with the ARB and other stakeholders to decide how to evaluate international certification programs to determine if they will meet California's goals and standards for sustainable production. To this end, the Energy Commission has joined the Roundtable on Sustainable Biofuels.

Previous year's sustainability funding has been spent on forest biomass sustainability research to implement the sustainability work plan developed by the Energy Commission for the Interagency Agency Forestry Working Group,[317] which aims to develop consistent definitions and standards for sustainable woody biomass from California's 40 million acres of private and public land forests. Substantial technical and scientific field work are needed to establish sustainability definitions and standards for the emerging woody biomass fuels industry.

For FY 2011-2012, the Energy Commission is allocating $2.5 million for sustainability research and technical support in the areas of biofuel feedstocks, water use concerns, potential of 3rd party sustainability certification programs to ensure sustainability, and manufacturing sustainability. At this time, sustainability research funding is not available through any other California regulatory programs such as AQIP or the federal ARRA program. Energy Commission staff has a standing offer to the Low Carbon Fuel Standard Sustainability Working Group to provide funding for research issues identified in their working group meetings.

Next, sustainability assessments need to be expanded from the project level to the regional level to develop a more comprehensive understanding of how increased bioenergy crop production in California could be integrated into existing cropping mixes without adversely affecting food crop or animal feed production, agricultural water use, or wastewater discharges. These studies could include the assessment of the environmental performance of current crops and regional assessments of energy crop expansion (such as Imperial Valley sugarcane, San Joaquin Valley sugar beets and sweet sorghum, or Sacramento Valley sweet sorghum). Similar regional studies for bioenergy crops such as algae and perennial grasses may also be needed as the commercial

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317 The Interagency Forestry Working Group was convened by the California Natural Resources Agency and California Environmental Protection Agency to develop consistent metrics for forest carbon accounting and sustainability definitions and standards for the energy and climate change programs at the California Air Resources Board and California Energy Commission.

viability of these crops and their associated process technologies mature. Specific studies are also needed on water use, wastewater discharge, land use, and fertilizer and pesticide inputs.

To ensure that water use reduction measures and best management practices are used in the production of biofuels, investigative studies are also needed that quantify water use for different types of biofuel production processes and for bioenergy crops. Examining water best management practices and emerging technologies that reduce water use and waste discharge could also be beneficial.

California will likely continue to depend on imported biofuel feedstocks and finished products to help meet GHG goals for the transportation sector. Investigating international environmental issues will be critical to ensure that all fuels used in California are sustainably produced. In-country field assessments of industry practices for the harvest and production of Southeast Asia oil palm, cane ethanol and oil palm in Brazil and greater South America, and African oil palm are needed to meet this goal. It is also important that there are field tests of international sustainability programs and third-party audits of international biofuels and feedstocks subject to sustainability certification programs along with examinations of habitat conservation and restoration efforts for areas affected by plantation development. Assessments of sustainability standards, protocols, and the efficacy of using sustainability certification programs in the United States and internationally could be very helpful in determining which sustainability certification programs are most relevant to California’s regulations and transportation needs.

Finally, California has the potential to attract many firms vying to capture market share in California’s green technology, alternative transportation sector and potentially locate manufacturing facilities in California. Manufacturing facilities – even for green technologies – have the potential to consume natural resources at non-sustainable levels (such as water), or to release toxic wastes into the air, water or land. The current sustainability goals and evaluation criteria for AB 118 were crafted to ensure sustainable use of natural resources associated with potential biofuels production. Different sustainability goals and evaluation criteria are needed to ensure a sustainable manufacturing sector for technologies associated with electric drive or other alternative powertrains.

Technical Assistance and Analysis

The Energy Commission will need continuous updates of the status of vehicle technology and fuels, market analyses, financing trends, and other factors that impact the introduction and growth of alternative and renewable fuels in California to monitor the progress of funding decisions and develop future, annual investment plans. Ongoing refinement of analytical methods, such as full fuel-cycle analysis models, will be needed to evaluate the potential GHG emission and other environmental impacts of new fuel and vehicle technology options. The Energy Commission has allocated $7.5 million in grants or contracts to fund this technical assistance and analytical work, which is likely to include the following:

- Ongoing technical support necessary to establish the life-cycle scale GHG emissions for new and emerging alternative fuel pathways that have not yet been analyzed in the LCFS program or through the Energy Commission's existing contract with Life Cycle Associates. The Program will need additional technical and training support with the

California-GREET model as it is expanded and updated to include new climate-changing gases, new fuel pathways, and sustainability parameters such as water.

- Full fuel-cycle analysis for new fuel pathways, to assist small companies in developing and demonstrating the carbon intensity of their alternative and renewable fuels.
- Technical assistance with evaluation of new technologies, and verification of claims made by applicants to the Program.
- An expansion of the California Biomass Collaborative's work to identify and quantify all California biomass feedstocks available for fuel production.
- Program measurement, verification and evaluation (MV&E) efforts. Statute requires the Energy Commission to evaluate the program's efforts in the 2011 Integrated Energy Policy Report, and in subsequently adopted reports. The goals of MV&E are to provide accountability and ensure effective administrative and financial performance of the program and its funding recipients. The Energy Commission will examine: 1) the expected benefits of the projects in terms of air quality, petroleum use reduction, greenhouse gas emissions reduction, technology advancement, and progress towards achieving these benefits; 2) the overall contribution of the funded projects toward promoting a transition to a diverse portfolio of clean, alternative transportation fuels and reduced petroleum dependency in California; 3) key obstacles and challenges to meeting these goals identified through funded projects; and 4) recommendations for future actions.

Table 32: Technical Assistance and Analysis Funding Allocation

Sustainability Studies	$2.5 Million
Technical Assistance and Analysis	$4.5 Million
Measurement, Verification and Evaluation	$3 Million
Total	$10 Million

Source: California Energy Commission

Chapter 6: Funding Allocations

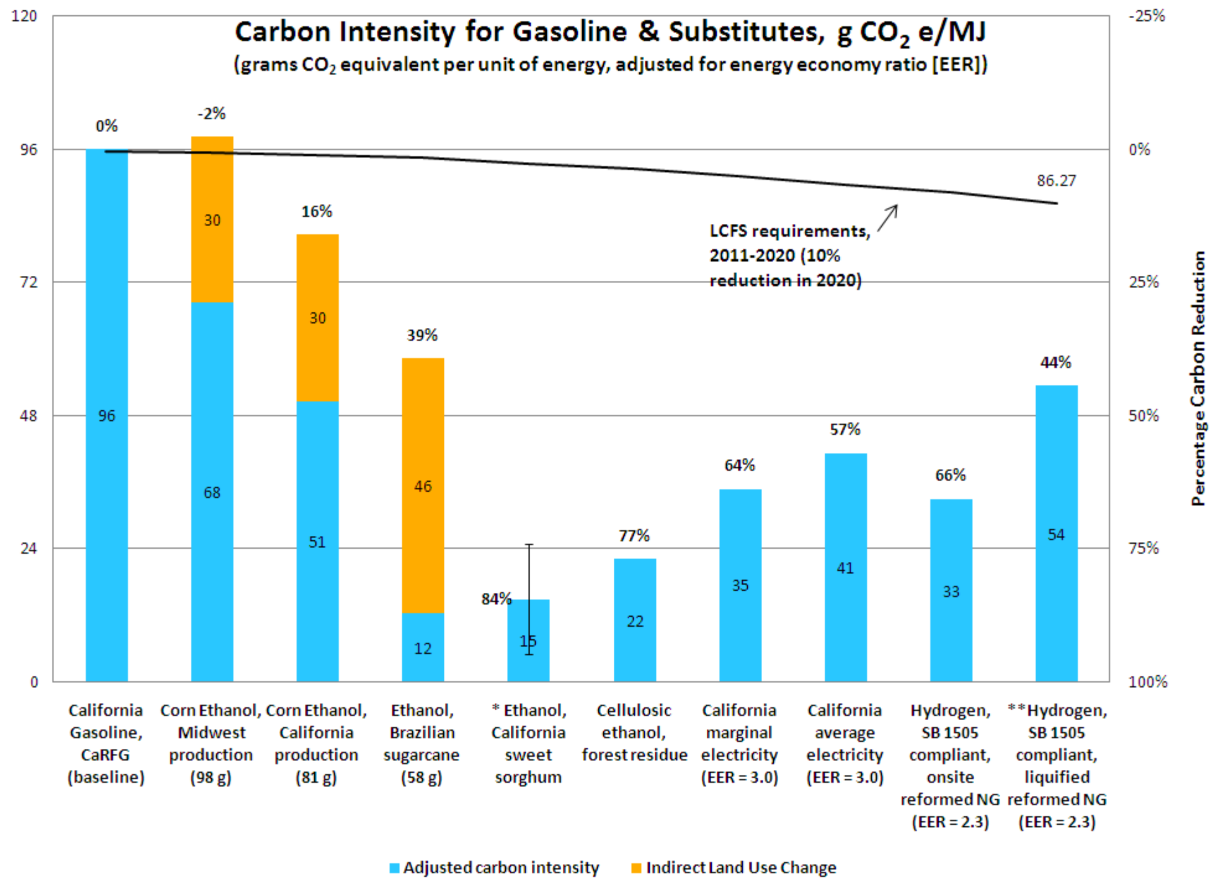
Table 33: Funding Allocation Summary for FY 2011-2012

	Project/Activity	Funding Allocation for FY (2011-2012)
Plug-In Electric Vehicles	Charging Infrastructure	$8 Million
	Subtotal	**$8 Million**
Hydrogen	Fueling Infrastructure	$3 Million
	Subtotal	**$3 Million**
Natural Gas	Fueling Infrastructure	$8 Million
	Subtotal	**$8 Million**
Propane	Light-Duty Vehicle Incentives	$1 Million
	Fueling Infrastructure	$.5 Million
	Subtotal	**$1.5 Million**
Ethanol	E85 retail	$5 Million
	Advanced Cellulosic Ethanol Production Plants	$7.5 Million
	Subtotal	**$12.5 Million**
Diesel Substitutes	Bulk terminal rack and fleet infrastructure	$4 Million
	Advanced Diesel Substitute Production Plants	$7.5 Million
	Subtotal	**$11.5 Million**
Biomethane	Pre-Landfill Biomethane Production	$8 Million
	Subtotal	**$8 Million**
Medium- and Heavy-Duty Vehicles	Deployment Incentives for Natural Gas Vehicles	$12 Million
	Deployment Incentives for Propane Vehicles	$3 Million
	Develop and Demonstrate Advanced Technology Medium- and Heavy-Duty Vehicles	$7 Million
	Subtotal	**$22 Million**
Manufacturing	Manufacturing Facilities and Equipment	$10 Million
	Subtotal	**$10 Million**
Workforce and Training	Workforce Development and Training Agreements	$5.5 Million
	Subtotal	**$5.5 Million**
Market and Program Development	Sustainability Studies	$2.5 Million
	Technical Assistance and Analysis	$4.5 Million
	Measurement, Verification and Evaluation	$3 Million
	Subtotal	**$10 Million**
	Grand Total	$100 Million

Source: California Energy Commission

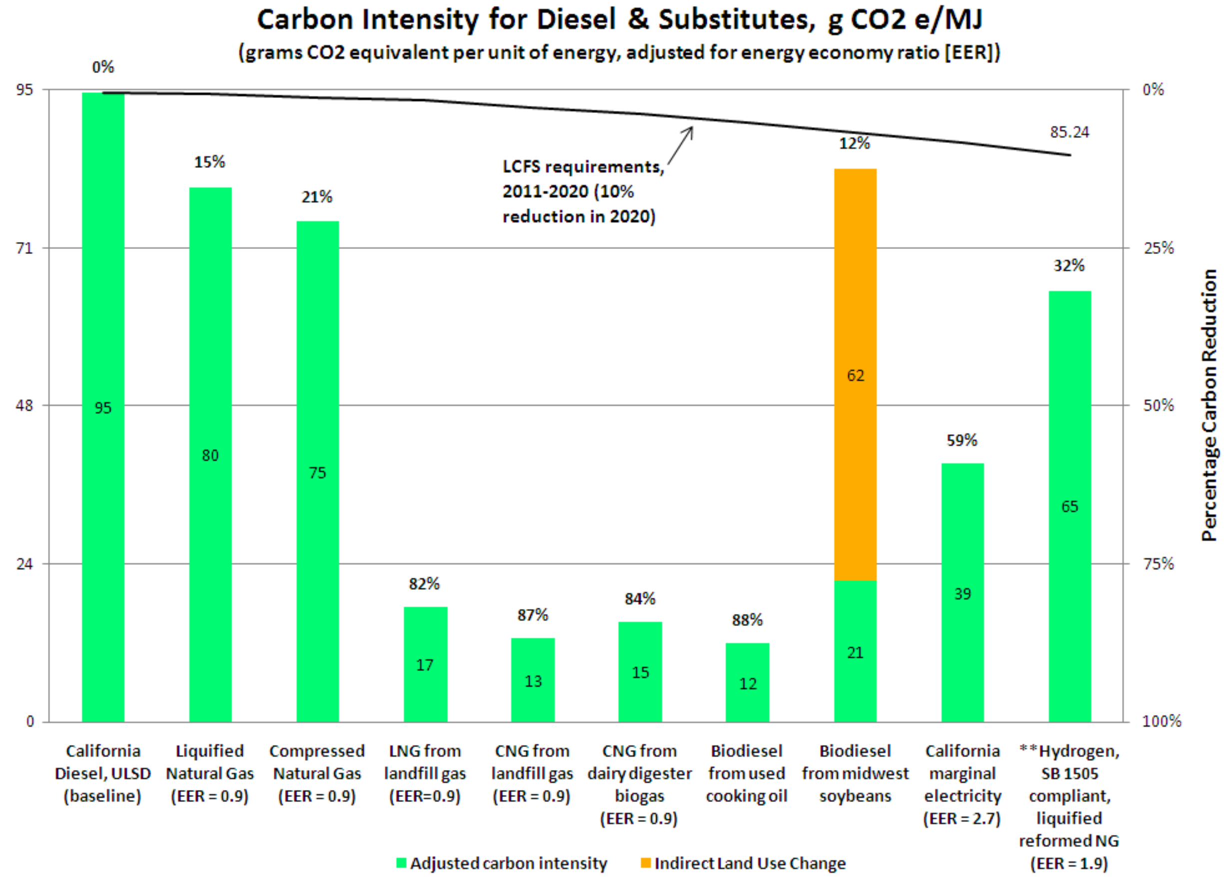
APPENDIX A:
Carbon Intensities for Fuel Pathways

Figure A-1: Carbon Intensity for Gasoline and Substitutes



Source: California Air Resources Board LCFS. *California sweet sorghum is an Energy Commission staff estimate; error bars indicate range of estimates; ILUC unknown. **Liquefied hydrogen is derived from ARB LCFS pathway document.

Figure A-2: Carbon Intensity for Diesel and Substitutes



Source: California Air Resources Board LCFS. **Liquefied hydrogen is derived from ARB LCFS pathway document.

APPENDIX B:
Hydrogen Fuel Demand and Supply

Table B-1: Hydrogen Fuel Demand and Supply

Year	Region	Kg Hydrogen Demand	Kg Hydrogen Capacity (Public)	Add'l Kg Hydrogen Needed	Changes in Regions' Hydrogen Supply (+/- Capacity)
2011	Santa Monica	55	170	0	West LA (+30), Westwood -UCLA (+140)
	Torrance	45	150	0	Torrance Pipeline (+50), Harbor City - Mebtahi (+100)
	Orange County	93	225	0	Fountain Valley (+100), Newport Beach (+100), UC Irvine (+25)
	Burbank	0		0	Burbank (+???)
	Los Angeles (other)	4	60	0	CSU LA (+60)
	San Diego	5		5	
	East Bay	9	60	0	Emeryville (+60)
	South Bay	13		13	
	San Francisco	6		6	
	Sacramento	22	100	0	West Sac - CaFCP (+100)
	Other	1	100	0	Thousand Palms (+100)
	Total	253	865	24	
2012	Santa Monica	67	710	0	Santa Monica (+180), Beverley Hills (+180), West LA (+180)
	Torrance	54	510	0	Hawthorne (+180), Hermosa Beach (+180)
	Orange County	115	800	0	UC Irvine (-25), UC Irvine (+180), Irvine North (+180), Laguna Niguel (+240)
	Burbank	0		0	
	Los Angeles (other)	4	240	0	Diamond Bar (+180)
	San Diego	7		7	
	East Bay	12	60	0	
	South Bay	13		13	
	San Francisco	14	240	0	SF Airport (+240)
	Sacramento	22	240	0	West Sac - CaFCP (-100), West Sac (+240)
	Other	4		4	Thousand Palms (-100)
	Total	312	2800	24	

2013	Santa Monica	80	710	0	
	Torrance	65	510	0	
	Orange County	198	800	0	
	Burbank	0		0	Burbank (-???)
	Los Angeles (other)	4	240	0	
	San Diego	3		3	
	East Bay	15	60	0	
	South Bay	13		13	
	San Francisco	22	240	0	
	Sacramento	25	240	0	
	Other	5		5	
	Total	430	2800	21	
2014	Santa Monica	277	570	0	Westwood -UCLA (-140)
	Torrance	183	410	0	Harbor City - Mebtahi (-100)
	Orange County	677	700	0	Newport Beach (-100)
	Burbank	0		0	
	Los Angeles (other)	24	80	0	Fountain Valley (-100), CSU LA (-60)
	San Diego	29		29	
	East Bay	64		64	Emeryville (-60)
	South Bay	36		36	
	San Francisco	44	240	0	
	Sacramento	48	240	0	
	Other	7		7	
	Total	1,389	2240	136	

Source: California Energy Commission

APPENDIX C:
PEV Deployments and Charging Infrastructure

Table C-1: PEV Deployments and Charging Infrastructure

Year	Region	(A) Vehicle Rollout	(B) Planned and Existing Level 2 Chargers*	(C) Level 2 Charger Demand*	(D) Additional Level 2 Chargers Needed*
2011	Bay Area				
	High density area				
	Northern California				
	Central Valley				
	Central Coast				
	Los Angeles				
	High density area				
	San Diego				
	Total				
2012	Bay Area				
	High density area				
	Northern California				
	Central Valley				
	Central Coast				
	Los Angeles				
	High density area				
	San Diego				
	Total				
2013	Bay Area				
	High density area				
	Northern California				
	Central Valley				
	Central Coast				
	Los Angeles				
	High density area				
	San Diego				
	Total				

	Bay Area				
	High density area				
	Northern California				
	Central Valley				
	Central Coast				
	Los Angeles				
	High density area				
2014	San Diego				
	Total				
	Bay Area				
	High density area				
	Northern California				
	Central Valley				
2015	Central Coast				
	Los Angeles				
	High density area				
	San Diego				
	Total				
	Total				

Source: California Energy Commission.
* Chargers are Level 2 public and commercial exisiting and planned. The number of chargers per vehicle is assumed to be 0.2 (and 0.5 for high density areas).

The regions in Table C-1 are comprised of the following counties:

Table C-2: Regions by County

Bay Area	San Francisco, Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, San Benito, Santa Cruz
Northern California	Sacramento, Yolo, El Dorado, Colusa, Sierra, Nevada, Placer, Yuba, Sutter, Lake, Plumas, Butte, Glenn, Tehama, Trinity, Lassen, Mendocino, Humboldt, Del Norte, Siskiyou, Modoc, Shasta
Central Valley	Amador, Alpine, Calaveras, San Joaquin, Stanislaus, Tuolumne, Merced, Mariposa, Mono, Madera, Fresno, Kings, Kern, Tulare, Inyo
Central Coast	Monterey, San Luis Obispo, Santa Barbara
Los Angeles	Los Angeles, Ventura, Orange, San Bernardino, Riverside
San Diego	San Diego, Imperial

APPENDIX D:
Fuel Conversion Processes

Table D-1: Fuel Conversion Processes for Non-Cellulosic Feedstocks

	Non-cellulosic Feedstocks				
	Fermentation[318]	Anaerobic Digestion	Transesterification	Thermochemical Processes	Algae
Description	Fermentation is the simplest process of producing ethanol. Yeast anaerobically converts sugar to alcohol and carbon dioxide.	In the absence of oxygen, “acid formers” convert volatile solids to fatty acids. “Methane formers” convert the acids to methane-rich biogas. The process occurs naturally in landfill cells, wastewater treatment plants, and manure lagoons, or can occur in specially constructed containers.	Oils are processed with methanol, a catalyst, and heat to produce trademarked Biodiesel, glycerin, and alcohol. Biodiesel must meet ASTM[319] D6751 specifications.	Gasification, pyrolysis, and depolymerization are applicable processes for non-cellulosic feedstocks. The descriptions of the processes are listed under the Cellulosic Feedstocks table.	Three primary stages: cultivation includes open, closed, and offshore[320]; harvesting/processing includes dewatering, fractionation, and extraction; conversion includes processing algae-produced carbohydrates and lipids[321]; direct synthesis of fuels[322]; or putting the algae directly into a conversion process[323].
Potential Feedstocks	Sugar cane, sugar beets, corn, wheat, barley and other grains.	Almost all organic material, including agricultural residues and woody materials (with	Plant, animal, and algae derived oils. Plant derived oils include vegetable, soybean[324],	Almost all non-cellulosic feedstocks. Some processing such as dewatering may be	Depending on algae and cultivation method, growth can be in solutions of sugar,

318 “The definition of cellulosic biomass ethanol . . . made at any facility – regardless of whether cellulosic feedstock is used or not – may be defined as cellulosic if at such facility ‘animal wastes or waste materials are digested or otherwise used to displace 90 percent or more of the fossil fuel normally used in the production of ethanol”, Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007

319 American Society for Testing and Materials

320 Open systems are typically open ponds. Closed systems include clear vessels known as photobioreactors or dark tanks. Offshore is growing contained algae in the ocean.

321 Carbohydrates to fermentation and lipids to transesterification or refinery process for gasoline, diesel, and/or jet fuel.

322 Alcohols (ethanol) and hydrocarbons.

323 Biochemical, thermochemical, and/or anaerobic digestion.

324 According to the American Soybean Association, for every 1.5 gallons of soybean oil derived Biodiesel, more than 6 pounds of protein-rich soybean meal is available for animal and human consumption.

		size processing to speed up decomposition and, with some cellulosic material, hydrolysis).	rape seed, and canola. Used oils from cooking are also used.	required, depending on the thermochemical process used.	municipal green waste, municipal wastewater, switchgrass, and/or cellulosic material.
Sustainability and Emissions	Well-to-Wheels (WTW) Mid-west corn ethanol – 65.66 gCO2e/MJ.[325] WTW Brazilian cane ethanol – 27.40 gCO2e/MJ.[326]	WTW Compressed landfill gas – 11.26 gCO2e/MJ.[327] WTW Compressed dairy digester gas – 13.45 gCO2e/MJ.[328]	WTW Cooking oil Biodiesel – 15.84 gCO2e/MJ.[329] WTW Midwest soybeans Biodiesel – 21.25 gCO2e/MJ.[330]	Varies with process and feedstock (see Cellulosic Feedstocks)	Reduced direct and indirect land impacts, fresh water not needed, non-competitive with food/feed production. CO2 can be used to enhance cultivation.[331]
Summary of Existing Projects	195 facilities nationwide producing 13,508 million gallons/year.[332] In California, 3 plants produce 120 million gallons/year.[333]	Altamont Pass Landfill – up to 13,000 gallons LNG/day.[334] Bowerman Landfill – 4,000 gallons LNG/day capacity. Hilarides Dairy	550 million gallons were produced in 2009 nationwide.[335]	Depolymerization: palm and vegetable oil – Neste Oil/Finland, Holland, and Singapore; chicken processing waste – Dynamic Fuels/LA	Sapphire/NM – open pond demonstration; Algenol/TX – photobioreactor pilot plant; Solazyme/PA – heterotrophic[336] pilot plant.

325 California Air Resources Board, Detailed California-Modified GREET Pathway for Corn Ethanol, February 27, 2009

326 California Air Resources Board, Detailed California-Modified GREET Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit; September 23, 2009

327 California Air Resources Board, Detailed California-Modified GREET Pathway for Compressed Natural Gas (CNG) from Landfill Gas, February 28, 2009

328 California Air Resources Board, Detailed California-Modified GREET Pathway for Compressed Natural Gas (CNG) from Dairy Digester Biogas, July 20, 2009

329 California Air Resources Board, Detailed California-Modified GREET Pathway for Biodiesel Produced in California from Used Cooking Oil, September 23, 2009

330 California Air Resources Board, Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME), December 14, 2009

331 Morello, Joanne and Ron Pate, The Promise and Challenge of Algae as Renewable Sources of Biofuels, DOE-EERE-Office of Biomass Program, September 8, 2010

332 Renewable Fuels Association, "Biorefinery Locations," http://www.ethanolrfa.org/bio-refinery-locations/, February 3, 2011

333 Pacific Ethanol, Calgren, Parallel Products

334 Ted Barnes, Altamont Landfill Gas Purification Testing and Monitoring – Critical project Review Draft Report, August 30, 2010

335 National Biodiesel Board

336 ". . . heterotrophic methods (where algae are grown without light and are fed a carbon source, such as sugars, to generate new biomass)", from National Algal Biofuels Technology Roadmap, DOE-EERE-Office of Biomass Program, May 2010, p. 8

Technology maturity and Companies working on technology	Corn/grain fermentation is mature. Three companies produce 1/3 of the ethanol: Archer Daniels Midland, Valero, and POET.[337]	Technology well established. Various landfills and wastewater treatment facilities pursuing capture of gas.	Commercial plants range from 1 - 40 million gallons/year. There is a 100 million gallons/year plant in Washington.		Four major R&D Consortia:[338]
Process cost	Corn ethanol production cost - $1.26 to $1.32 per gallon in 2012 (2004 dollars)[339]	Cost varies with digester technology and scale of production.[340]	Feedstock costs are 80 percent of the final fuel cost. Larger plants are more profitable.	Varies with process and feedstock. Depolymerization economically competitive at $80-$120/bbl crude oil prices.	Not yet known and will vary on the process used.
Market potential	Ethanol is not new to transportation sector and market already has necessary production and distribution mechanisms in place.[341]	Current low price of natural gas is making biogas harder to compete on production cost basis.	Existing plants are underutilized.	Considered as having market potential based on the type of fuel produced. Fuels are compatible with petroleum infrastructure, pipelines, and engines (including jets).	Potential yields of at least 700 gallons of oil/acre/year.[342]

337 Renewable Fuels Association, "Biorefinery Locations," http://www.ethanolrfa.org/bio-refinery-locations/

338 National Alliance for Advanced Biofuels and Bioproducts, Cellana Consortium, Consortium for Algal Biofuels Commercialization, Sustainable Algal Biofuels Consortium; from Morello, Joanne and Ron Pate, The Promise and Challenge of Algae as Renewable Sources of Biofuels, DOE-EERE-Office of Biomass Program, September 8, 2010

339 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007

340 Patrick Chen, et. al., Economic Assessment of biogas and Biomethane Production from Manure, March 20, 2010

341 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program; Final Rule, May 1, 2007

342 Comparable gallons of oil/acre/year: corn – 18, soybeans – 48, sunflower – 102, rapeseed – 127, palm – 635.

Gap analysis		Support with capital investments for equipment, interconnection fees to natural gas pipeline.	2010 estimates are 70 percent less than 2008[343] due in part to issues with underground storage tanks[344] and 12/31/09 expiration of fuel subsidy.	Support with improved feedstock processing and transport.[345]	Renewable Fuel Standard is a policy driver for algae fuel R&D. Algae derived biofuels show potential.
	California Energy Commission solicitations for biofuels to include above processes. Responses to previous solicitation included applications in all the technologies and feedstocks discussed in this table. Application requests were greater than amount available.				
Primary transportation fuel product	Ethanol	Biogas, compressed and/or liquefied	Biodiesel	Syngas, diesel, gasoline, ethanol, methanol, jet fuel, and dimethyl ether	Ethanol, Biodiesel, gasoline, diesel, jet fuel

Source: California Energy Commission

343 California Board of Equalization, Clear and Dyed Biodiesel Transition Reported by Diesel Fuel Suppliers Jan-05 to Dec-08.
344 California governmental policies have had a chilling effect on Biodiesel production. The 2008-2009 State Water Resources Control Board's actions that prohibited Biodiesel blends greater than 5 percent in underground storage tanks has identified as a key impediment by producers.
345 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

Table D-2: Fuel Conversion Processes for Cellulosic Feedstocks

	Cellulosic Feedstocks				
	Thermochemical Conversion[346]			Biochemical Conversion[347]	Other[348]
	Gasification	Pyrolysis	Depolymerization	Hydrolysis	
Description	There are two general classes of gasifiers: partial oxidation and indirect. Indirect gasifiers use steam as the gasifying agent. The primary product of gasification is a synthesis gas or syngas that may be cleaned and used as a fuel gas or as the feedstock for other fuel production processes[349].	Pyrolysis thermally breaks down biomass into pyrolysis oils at lower temperatures than gasification. The primary product is a liquid instead of a synthesis gas. Pyrolysis oil requires further treatment be used to produce gasoline and diesel fuel.	Depolymerization includes two stages. The hydrothermal upgrading stage is water slurry pulping and heating under pressure, flashing, and cracking the produced oil. The hydrotreating stage uses hydrogen, heat, and pressure to break the light hydrocarbons into fuels for vehicles and jets.	The full process begins with size reduction and pretreatment with heat, pressure, acid, or base to break up lignin and hemicelluloses. Cellulose and hemicellulose are converted to sugars via enzymatic or acid hydrolysis. Sugars are fermented or used in some other fuel conversion step.	Other processes include hybrids of thermochemical and biochemical processes, hybrids of thermochemical or biochemical conversion processes with new processes, and all-new technology processes.
Potential Feedstocks	Any cellulosic biomass material including agricultural residues such as corn stover, rice straw, wheat stalks, sugarcane and sorghum bagasse, perennial grasses such as switchgrass and *Miscanthus*, woody crops such as poplar and willow, and forestry residues.				

346 Thermochemical conversion involves biomass being broken down using heat and upgraded to fuels using a combination of heat and pressure in the presence of catalysts.

347 The general process of most biochemical cellulosic biofuel process consists of feedstock handling, pretreatment, hydrolysis, fermentation or fuel conversion, and a final distillation/separation step.

348 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

349 Syngas to Fischer-Tropsch is the leading method for producing diesel substitute fuel. Fischer-Tropsch produces a paraffin wax that can be refined into diesel, jet fuel, and naptha.

Sustainability and Emissions	Well-to-wheels GHG for cellulosic ethanol from forest waste via gasification is 22.20 gCO2e/MJ.[350] Biomass derived Fischer-Tropsch diesel: approx. 88 percent GHG reduction.[351]	California GREET well-to-wheels GHG analysis not conducted. For forestry waste: collection is 8.61 g/MJ, transport is 3.67 g/MJ, and CO2 credit from not burning is -130.15 g/MJ.		Well-to-wheels GHG for cellulosic ethanol from farmed trees by fermentation is 2.4 gCO2e/MJ.[352]	Information not found for cellulosic feedstock.
Summary of Existing Projects	There are more than 50 fully commercial thermochemical facilities in Japan, Germany, and the United Kingdom.[353]		Existing projects currently use palm oils. See Non-Cellulosic table.	Enzymatic hydrolysis to ethanol: AE Biofuels (California), DuPont Danisco Cellulosic Ethanol (Tennessee), KL Energy (Wyoming).[354]	Primarily in R&D.
Technology maturity[355] and Companies working on technology[356]	With Fischer-Tropsch: Choren, Flambeau River Biofuels, Baard, Clearfuels, Gulf Coast Energy, Rentech, TRI, Nature's Fuel, Chemrec, New Page. With catalytic	National Renewable Energy Laboratory investigating stabilized higher quality oil. Dynamotive Energy Systems.	Hydrothermal upgrading is 8 years old and requires R&D. Hydrotreating is a 3 year old commercial technology.[357] Green Power Inc., Cello Energy.	EPA is tracking progress of more than 70 facilities. Several companies (e.g. Abengoa, BlueFire Ethanol, Coskata, Fulcrum, POET, and Vercipia) intend to have	Processes are considered second generation or new. Coskata, INEOS Bio, Lanzatech, Zeachem, Virent.

350 California Air Resources Board, Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Forest Waste, February 27, 2009

351 Well-to-Wheel assessments by California Energy Commission, ConocoPhillips, Sasol Chevron, Shell International.

352 California Air Resources Board, Detailed California-Modified GREET Pathway for Cellulosic Ethanol from Farmed Trees by Fermentation, February 27, 2009.

353 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

354 Federal Register, "Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards," http://www.federalregister.gov/articles/2010/07/20/2010-17281/regulation-of-fuels-and-fuel-additives-2011-renewable-fuel-standards#p-127

355 The technology process components (gasification, pyrolysis, Fischer-Tropsch, etc.) are in commercial use. Advancements are being made in making the process more efficient, providing higher quality products, new catalysts, and hybridizations.

356 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

357 Status of Neste Oil's Biobased NExBTL Diesel Production for 2007, Neste Oil, Synbios, Stockholm, May 19, 2005

	conversion to ethanol: Range fuels, Pearson Technologies, Fulcrum Bioenergy, Enerkem, Gulf Coast Energy.	Pyrolysis with Depolymerization: Dynamotive, Envergent, Petrobras[359]		commercial sale of cellulosic ethanol in 2012.[358]	
Process cost	Varies with technology and feedstock.	Varies with technology and feedstock.	Process cost varies based on efficiencies at converting feedstock energy content (50 percent to 80 percent).	Production cost of gallon of cellulosic ethanol: $1.65 in 2012 (2004 dollars) or 31 percent higher than corn ethanol using same parameters.[360]	Not yet quantified. Environmental Protection Agency is tracking processes for Renewable Fuel Standard.
Market potential	The Environmental Protection Agency acknowledges that the cellulosic biofuel industry is progressing at a rapid pace and is tracking the progress of more than 100 cellulosic biofuel projects. The technologies also have application for municipal solid wastes processing.[361]				
Gap analysis	Improved pre-processing of feedstock material and methods to use lignin in biochemical processes.[362] Fuel incentives for cellulosic biomass based fuels. California Energy Commission solicitations for biofuels to include above processes.				
Primary transportation fuel products	Syngas, diesel, gasoline, ethanol, methanol, dimethyl ether.[363]	Diesel, gasoline, jet fuel.	Diesel and gasoline.	Ethanol	Varies.

359 Ibid.

358 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

360 Ibid.

361 Conversion Technologies Status Update Survey, Publication #IWMB-2009-008, Integrated Waste Management Board, April 2009

362 Federal Register, 40 CFR Part 80, Environmental Protection Agency, Regulation of Fuels and Fuel Additives: 2011 Renewable Fuel Standards/Final Rule, December 9, 2010

363 Requires syngas to Fischer-Tropsch, biochemical, or some other process to convert to liquid transportation fuel product.